REPORT

OF THE

CHIEF ENGINEER

OF THE

NEW YORK & BROOKLYN BRIDGE,

JANUARY 1, 1877.

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To Hon. Henry C. Murphy, *President Board of Trustees of the New York and Brooklyn Bridge :*

Sir :—

I beg leave to submit herewith my report for the year ending 1876, and as no report was made of last year's operations, that will also be included.

The amount of work that has been done during the past two years is so great, and of such varied character, in order fully to describe all the operations gone through with and do full justice to all the details, I will include with this the full reports of my assistants, each one giving detailed account of the operations, that were conducted under his direct supervision.

As the work is all the time in progress, most of my time is taken up in arranging for the immediate conduct of operations, hence these remarks will be concise.

MASONRY.

Both towers and anchorages have been completed as far as may be, during this time. The small quantity yet remaining to be put on the anchorages and towers cannot be laid until the cables are completed. Much of the material for this purpose is on hand.

In all suspension bridges the masonry usually forms about one-half of the total work to be done. We may therefore congratulate ourselves that we have this much behind us.

The work henceforward will be of an entirely different character. Our towers and anchorages, as they stand, challenge comparison with any masonry in the world, as regards solidity, the material of which they are built, and the careful manner in which that material was laid, and considering the great height to which most of these stone had to be raised, it was done at a minimum cost and a great rate of speed, the only delays experienced being caused by want of stone. These delays are not to be wondered at, when it is remembered that the stones used were cut, over six hundred miles away, and gathered from at least twenty scattered quarries, with boisterous seas intervening between them and the place of delivery. Out of the thousands of ship loads of stone sent, only one was lost.

The machinery for delivering the stones on top of the towers was so adequate that it cost no more per yard to lay the top courses than the bottom ones. This implies something, when it is borne in mind that the summit of the New York tower is 345 feet above the foundation.

TOWERS.

The arches of the Brooklyn tower were completed in the spring of 1874. The line of thrust in these pointed arches falls about two and a half feet outside of the centres of the side shafts at the floor line, but the main outer cables, when drawn in laterally, modify its position to such an extent as to throw it six inches inside of that point; a condition of the utmost stability.

The keystones, huge blocks weighing 11 tons, were fitted in without trimming, just as they came from the quarry, showing that the thickness of joints between the voussoirs was regulated with the proper accuracy as the arch was built up.

On completion of the tower, heavy castings, comprising the saddles and saddle-plates, were raised at a single lift, and with great despatch, and hoisted into place without any mishaps. In general form they do not differ materially from those used on the Cincinnati Bridge, except that they are about twice the size.

The diameter of the saddle-rollers is 3½ inches. Rollers of larger diameter would be too sensitive, which is not desirable. Rollers of smaller diameter would be too sluggish. The length and number of the rollers are properly proportioned for the load resting upon them.

It is not expected that these saddles will move under any passing load after the Bridge is completed. The varying strains will be amply resisted by the mass of the tower; but during the construction of the Bridge, the saddles are sure to move. The direction and extent of this movement are somewhat uncertain. We have no precedent just like this bridge, nor any data on which to base accurate calculations. I have placed the saddles 12 inches back from the centre towards the land sides, a position where we will be on the safe side, no matter what the movements may be.

Besides the reception of the main cables, the saddles had to be arranged for the making of the individual strands above them. They also serve, together with the plates, to hold a number of overfloor stays, which are 30 in number, on each side of the towers. The bulk of these stays will be secured to large irons, a double tier of which have been built into the masonry underneath the saddle-plates, extending entirely through the tower.

ANCHORAGES.

For the details of these massive pieces of masonry, I would refer to the annexed report of Mr. Collingwood.

The obstacles met with in the progress of the work are there fully detailed. The great weight and size of all the materials handled required apparatus of the strongest kind, combined with constant exercise of care and judgment.

The light timber foundations are in each of the anchorages located below the fresh water level, thus insuring their permanent preservation.

ANCHOR PLATES.

Before alluding to the reasons which govern the designs for the plates, the chains, and some of the other arrangements, I will mention that the resistance offered by the weight of the masonry on the plates, against the upward pull of the chains, affords a margin of safety of $2\frac{1}{2}$ times. This figure may appear small when compared with the main cables, where the margin of safety is *six* times, were it not that the conditions are essentially different. In the case of the cables, we have to provide for numerous contingencies which cannot occur in the anchorage. For instance, allowance must be made for the deterioration of the wire by the elements, for any possible imperfection in the manufacture of the cables, for any increase in weight or strain over that first contemplated, which is most always the case, and lastly, a certain margin is required so as not to strain the wire beyond its limit of elasticity.

In the anchorage, however, we have only two factors to deal with—granite and gravity. The first, a material whose very existence is a defiance to the "gnawing tooth of time;" the second, the only immutable law in nature; hence, when I place a certain amount of dead weight, in the shape of granite, on the anchor plates, I know it will remain there beyond all contingencies.

In the *anchorage plates*, which are huge spider-shaped castings, two alternative designs were possible. Either to make them in one solid casting, or to divide each casting into a number of separate thin plates between which the chains would be inserted, the whole being united by wrought iron bars, as proposed by Mr. Allen. Castings in large masses seldom show the same rate of strength which the same metal will give with a small sectional area ; but it was found easily practicable to keep the greatest thickness of metal in these plates within three inches, and as every other advantage remained with the single casting, the latter plan was carried out with perfect success. The thickness of metal and the distribution of the various parts of these castings also guarantee the absence of internal strains.

ANCHOR CHAINS.

The anchor chains are so disposed as to form the quadrant of a circle extending from a point 26 feet above the anchor plate, to which they are joined by a vertical section, to within 25 feet of the front of the anchorage, the cable itself emerging eight feet below the top of the masonry. This distance of 25 feet is necessary in order to compress the spreading strands of the cable within their proper bulk, before emerging from the masonry. In the arrangement of these chains, various conditions and conflicting requirements had to be fulfilled. The chief point, governing all the others, was a proper attachment of the end of the chain to the strands of the cable.

In all previous wire-cable bridges, each cable was composed of seven strands. This division was impossible here, as the strands would be too bulky to handle, and could not be properly laid up, when exceeding a certain diameter. The next number of strands giving an approximation to the figure of a circle is thirteen, but here the strand was still too large, for the reasons above given, so that nineteen strands were finally determined on.

These required 38 bars at the ends of the chains for their attachment. The bars are arranged in four tiers, thus occupying a minimum amount of space—the attachment being further made in such a manner, and in such order, that the strands will lie comformably to the circular arrangement in the saddles on the towers, and at the same time permit each new strand to be made on the end of the chain, so as not to be interfered with by the strands already in place.

The next question was the choice of material; whether to use iron or steel for these bars. During a visit at Mr. Krupp's works, in Essen, during the year of 1867, the managers obligingly forged for my inspection an anchor bar 2x9, but would not guarantee any greater strength than 80,000 lbs. per square inch of that section of steel. A subsequent comparison of relative rates of strengths and prices soon showed that iron would have the preference over steel.

Iron has been used. and I think the choice a wise one. To build up an iron chain of such dimensions in one flat tier, as had been previously the practice, was also impossible. Not only would such a chain have been 12 feet in width, but a tight-fitting pin of that length would have to be driven through 40 eye-holes—a problematical proceeding in any event, independently of the fact that the width of the anchor walls would not admit of the driving of so long a pin. These difficulties were overcome by building up the chains in two separate tiers, one on top of the other, and separated by the proper knuckle plates. At one point these chains are united by thrust and tie bars, so as to counteract any evil results that might follow from attaching one-half of the cable to the lower tier, before the upper tier is subjected to any strain.

As regards the section of the chain at various points, we find that its curved position reduces the strain from the cable to the plate about one-third, which is due to friction of the link heads on the knuckle plates. It is also almost certain that the adhesion of the chains to the cement, and the hold they have in the masonry, reduces this strain nearly one-third more, though it was not deemed expedient to take any account of this additional safety, in calculating the size of the plates and chains.

The change in section of chain area is accomplished by gradually increasing the size of the bars, as well as their number. The increase in number being required for the compact and symmetrical arrangement of the strand shoes at the end of the chain.

PRESERVATION OF THE ANCHOR CHAINS.

The preservation of the anchor chains from rust is effected in the manner customary on previous works, by properly painting the chemically-cleaned surface of the iron and then embedding the chain in hydraulic cement. The preservative qualities of hydraulic cement have been well tried by long experience.

When the old Pittsburgh Aqueduct was dismantled, a few years since, the anchor chains, after sixteen years of service, were found in a perfect state of preservation. This fact was again corroborated in the case of the anchorage of the Niagara Bridge, by an inspection made at the instance of the Canadian government two years ago, after having been immersed in water-bearing strata for 22 years.

In European suspension bridges the chains are usually carried in tunnels open to access, which are confidingly left to the care of future generations, and this trust is not betrayed. This, however, is contrary to the genius of the American people; with whom everything has to look out for, and take care of itself; hence, in the arrangement of this anchorage the chains are inaccessibly preserved, and are not intrusted to the neglect of posterity.

I may say in this connection, that after eight years of observation, I am convinced that the rusting power of the

Brooklyn air is fully twenty-fold greater than the air of localities in the interior, Cincinnati, for instance, where the smoke impregnated atmosphere is an ample protection of itself.

CABLE WORK.

The main cables consist of 19 strands. These strands are not made on land and hauled across the river, but are laid up in place; and, as they cannot be made in the position which they are finally to occupy in the cable itself, each separate strand is laid up, 60 feet above this position.

By doing this we gain not only the advantages of the strand being out of the way of those already made, but also of laying up each wire under a strain of 400 pounds, thereby testing it to a certain extent throughout its whole length, and eliminating all bends or crooks. Moreover, the regulation of the tension could not be accomplished in the low position.

A uniform tension is secured by giving each wire the same deflection. This work is done by men called "regulators" stationed on light platforms called "cradles," in the centre of the main span, and each of the land spans. An intermediate set of cradles is also provided in the main span for the better control of the wire between the towers and the regulators, so that in all, 10 cradles are required; whereas, one sufficed in previous works.

After being oiled, and the ends joined together by steel ferrules, the wires are wound up on large drums at one of the anchorages, and are thence transported across the river, two at a time, by an endless "working-rope." This rope is propelled forwards and backwards by an engine and a driving-wheel, and carries a "traveling sheave" upon which the wires run.

When a set of strands is completed, they are detached from their temporary fastening at the anchorage by means of powerful tackle, let forward to the permanent fastening at the end of the chains, and also lowered into the saddles on the towers to their proper place in the cable.

All four cables are made simultaneously. After the first 12 of the 19 strands are completed and regulated, seven of them are compressed together to form a centre core around which the remaining strands are afterwards placed, and the whole continuously wrapped with wire.

The cables are made about five or six feet above the position they will occupy after all the settling has taken place. This settling is due to the following causes:

First, the deflection due to the load. This, for steel wire, would be at the rate of $\frac{8}{100000}$ of a foot per foot length, per gross ton of strain per square inch of section.

Secondly, an allowance must be made for any forward movement of the saddles. The uplifting action of the stays in the quarters will also cause a depression in the centre of a little more than two feet.

Lastly, changes of temperature must be provided for, so that the floor cannot fall below the limit fixed by law.

The length of time required to make the main cables is largely dependent on the wind and weather, and will require no less than 2½ or three years. This estimate of time is based on the experience at Cincinnati, where it took nine months to lay up a million of pounds of wire into cable. According to that it would take six times nine months for the cables here; but by making two pairs of cables at once, we reduce this to three times On the other hand, our bridge is two and a half times as long between anchorages as at Cincinnati, and the interruption from wind will be fully twice as great. This, again, is offset by the fact that our wire here being a larger size, we can lay up a greater bulk in weight in the same length of time. Taking all these things into consideration, we see that the above estimate of time is correct.

Preparations for the commencement of cable-making have been going on for two years past, during which time the required machinery for running out the wire from the Brooklyn anchorage has been put up, and is only awaiting the completion of the foot-bridge for an active commencement.

The cradles are supported by heavy wire ropes, suspended at such a deflection that the main strands, while being made, hang directly opposite the " regulator," thus giving him every facility for handling the wires. Access is had to the " cradles " by means of a light, temporary foot-bridge.

Two designs were made for this foot-bridge ; one in a low position, at the level of the floor of the main bridge ; the other 60 feet above, at the level of the cradles and strands. Both positions have their advantages and disadvantages. From the low foot-bridge the regulating of the strands in the cables can be easier accomplished, but access to the cradles could only be had by means of long, vertical rope ladders, difficult and dangerous to climb. The intermediate cradles would have been almost inaccessible. Provision for safety against storms could perhaps be equally well made in both cases. The upper position involves much heavier strain in the ropes, but the putting in place could be more easily accomplished. The important consideration which led to the adoption of the high position was the accommodation of the shipping, since the low foot-bridge would have at once formed a barrier across the river at a uniform height of 150 feet above the water, whilst the upper position gave 210 feet height ; which head-room would be maintained for a year or more, when the lowering of the cable strands would slightly curtail it.

ROPES ACROSS THE RIVER.

A general plan for getting the ropes across the river, and suspending them, was sketched out some years ago, and has been successfully carried out. It consisted mainly in laying the lighter ropes, including a "carrier rope," in the bed of the river, from which they were raised over the towers by engines located on each side. All the heavier ropes were then taken across on the "carrier rope" by means of carrier sheaves, and after being hauled taut, were fastened to irons secured in the masonry of the anchorage. But little delay was caused by the passing vessels, notwithstanding the fact that the East river is one of the most crowded rivers in the world and that no less than a hundred craft often pass the line of the Bridge during an hour.

The taking over of the first heavy rope of course suggested many improvements, which greatly facilitated the work of getting over the remaining ropes.

FOOT-BRIDGE FLOOR.

The platform, or floor, of the foot-bridge, 3½ feet wide, is composed of wooden strips with a small space between them, laid on top of the ropes. No suspenders are used. To protect such a frail structure against the violence of terrific gales, that rage here almost weekly, is no easy task, and I venture to predict that, notwithstanding every precaution, our temporary works will be disabled more than once before we have completed cable making. The principal security against the wind is a pair of inverted storm cables, assisted by a number of "underfloor stays" in the main span. In the land span the guys lead directly to anchorages in the ground. In addition to these, the ropes are secured together laterally.

It is of but little moment how much the cradles may sway about in the middle of the main span, but all great waves must be checked before they reach the towers where alone the ropes can be injured. This is done by the "underfloor stays," and by securely fastening the ropes to the masonry.

The inverted parabolic storm cables serve rather to prevent the foot-bridge being carried away bodily.

FOOT BRIDGE ROPES.

As the difficult work of getting these ropes over was more directly in the charge of Mr. Farrington, I beg to refer the reader to his report, which will be found annexed. An ample training in this kind of business at Cincinnati and Niagara Falls had especially fitted him for such work, and it is to his care and judgment, combined with the efficient aid rendered by Mr. Martin and Mr. McNulty, that we owe the success of those dangerous operations, without a single accident or loss of life up to the present time.

For a full description of the steel-wire ropes I would refer to the specifications, subjoined hereto. The contract for these ropes was let to the Chrome Steel Co., of Brooklyn, E. D., and they were manufactured by the John A. Roebling's Sons Co., of Trenton, New Jersey.

CABLE WIRE.

As may be supposed, the question of the main cable-wire has formed the subject of much reflection and thought; especially in preparing the specifications for the same. Tests have been going on at intervals for the past six years, and constantly during the last two years. The making of the tests was entrusted to my able and efficient assistant, Col. Paine, and were carried out under my own immediate supervision. In the course of these experiments Col. Paine has elicited many new and interesting facts. Samples were obtained from most of the principal foreign as well as domestic makers of steel wire, comprising all the various grades of steel, but especially cast-steel, and these samples were in no case especially prepared to exhibit any extraordinary qualities but were the ordinary products of the works, and made at a reasonable cost.

The principle which served as a guide in these determinations, was to obtain a certain rate of strength for the least amount of money.

It was discovered at a very early day that a comparatively slight raise in the requirements, for instance, raising the rate from 160 to 170,000 or 180,000 lbs. per square inch, made a much larger proportional increase in the price; whereas a reduction of the rate below these figures did not affect the price very much.

It was from the full data obtained from these extensive experiments that the first sketch of our requirements in tests was built up This was then modified to suit this particular case. As the wire specifications, which are appended to this report, go very fully into the reasons which led to these different conclusions, little is left for me to say here.

The choice of the particular size of wire selected proved very fortunate, not only in respect to cable-making, but also in respect to the making of the wire itself Had a coarser size been taken, it would not have been possible to develop the degree of strength, and the increased cost of a smaller size would not be compensated by any other advantage.

The gauge of the wire is given at No. 8, full (Birmingham), which means anywhere between the No. 7½ and No. 8. Every practical wire drawer knows that wire gauges differ, not only in different establishments, but in the same establishment, and that they constantly wear out and get larger. To avoid this trouble, the weight of the wire has been fixed at 14 feet to the pound.

The first thing, therefore, to be done by the contractor, is to draw some wire from the stock he proposes to use, until he gets a piece of exactly such a weight; this wire then forms the standard by which his whole product is gauged.

It is evident that the rate of strength per square inch is entirely governed by the specific gravity of the material. Under the specifications we would probably have to deal with every variety of steel, from the light carbon steels with 1½ per cent. or more of carbon, down to Bessemer, containing often less than one-fourth per cent., and from that to the still heavier Chrome Steel.*

In order to embrace all of these, the weight is fixed at 483.84 lbs. per cubic foot, which represents the rate of 160,000 lbs. per square inch for wire of which 14 feet weighed one pound. Now, if the material which the contractor uses should prove lighter than the figure fixed above, he will be obliged to slightly increase the diameter of his wire, in order to make it weigh 14 feet to the lb. If his material is heavier, the reverse will be the case. The effect of this will be to make a slight change in the diameter of the whole cable, and also in the rate of strength per square inch; that is, it will give a lower rate with light wire and a higher rate with heavier wire; but *as long as each cable contains* 6,300 *wires, the breaking strength of each one of which is fixed at* 3,400 *lbs., it is impossible that any variation can be brought about in the ultimate strength of the cables; and, further, as long as every wire weighs* 14 *feet to the lb., it is impossible that the total weight of the cables can be changed in any way.*

While I am discussing this question of ultimate strength, I will say it is a matter of very little importance to me whether the ultimate strength of the wire given in the specifications is a little greater or little less than 160,000 lbs. per square inch. The ultimate strength was inserted in the specifications, because it is customary, and is better understood by the wire makers for whom these specifications were written. As long as

*Average weight of 12 specimens of Chrome Steel as given in the Circular of Chrome Steel Co., of January, 1874, is 488.92 lbs. per cubic foot.

I am sure of an elastic limit of 1,600 lbs., and that the maximum strain on each wire in the cable will be of about 570 lbs., I am absolutely safe beyond all contingencies, even if every wire were to break with 3,000 lbs. strain.

The determination of the ultimate size and strength of the cables is governed by another set of considerations of a different character, but of equal importance. They have already been spoken of under the head of anchor chains.

QUALITY OF WIRE.

Throughout this whole investigation it has been felt that one grave difficulty surrounded the question of steel, and that is, lack of uniformity of quality. This question is so serious that, were it not for the manifold advantages to be obtained, steel would not have been used.

The experience gained by the tests made at the Bridge, as well as personal experience of twenty years in handling thousands of tons of steel, in the wire rope business, have shown that all steel is, within limits, very uncertain in its character; a fact applying with much greater force to the high and more expensive crucible cast-steels than to the other medium qualities.

Even with the best intentions on the part of the maker, it is very doubtful if successive lots of any amount will turn out exactly the same. In a private business this point can be more easily settled. The reputation of the maker would be the leading consideration; further, the price has something to do with the quality; and lastly, as the amounts of steel handled are usually small, it is easy to change from one maker to another if the steel turns out badly.

Such a course is manifestly impossible in the case of a work of the magnitude of the East River Bridge, and least of all, in a city like New York. What then was to be done? To invite the bidders to make a few rings was well enough in its way. It would serve to show the engineer what the bidder could do, and instruct the bidder as to what had to be done ; but to assume that a few rings would be a sure guaranty for the whole contract, could not be thought of.

To acquire any reliable knowledge as to the uniformity of any maker's product, would require an order of at least 50 tons, and by the time this was distributed among all who could do the work, it would amount to giving out the contract piecemeal, without any competition.

The plan adopted was, therefore, the only one that could be practically executed, namely: to invite public competition with a view of awarding the contract to the lowest bidder, and, on the other hand, to exact a large bond for the faithful performance of the contract; and, finally, to secure the qualities called for in the specifications by a complete system of tests. The assurance of the correct performance of these tests must remain a matter of confidence and trust. The building of the whole Bridge is a matter of trust.

Among other questions which came up was a minor one respecting the advisability of limiting the competition to wire makers, or extending it to the whole steel trade.

My views on this matter are contained in the following letter addressed to my assistant, Colonel Paine, on Oct. 16th, 1876.

" Dear Colonel :

In your letter of the 14th you inquire whether a rigid adherence is expected in regard to that item of the cable-wire specifications which excludes all but wire makers from putting in bids.

I would say in reply that there are many weighty considerations for adhering to this stipulation, and only one poor reason for not doing so; the latter being a weak desire to please everybody, a course which inevitably ends in disastrous complications, from which you can only extricate yourself by great effort and expense of time and money. All of which can easily be avoided at the outset.

In the first place, I believe it to be an accepted fact, that the wire maker makes wire; so it is, therefore, perfectly natural, that in our specifications we should call for wire makers to give us bids ; but it would seem very odd if we should invite bids of a man who has an ore-bed or a coal mine, or who sells pig iron, or steel ingots, or blooms, or billets, or bars, or rods, or lumps of zinc. All these operations culminate in the final product of the finished wire made by the wire maker. He is the last man in the chain, and must, of necessity, be the one who fixes the market price of *wire*.

In the next place, if a wire maker should get this contract, he must have perfect freedom to buy his steel wherever he pleases, and must not be tied down to the use of any one person's product. There are a thousand steel makers in the world, and if one man's steel will not answer, another's may. He can thus always help himself if his wire does not come up to the mark. Parties who are not wire makers will only bid for the sake of pushing in their own particular brand of steel. They will take good care that it shall stand the preliminary tests, even if they have to buy a piece of steel for this purpose. For this reason I attach little value to our preliminary tests as a sample of what is to come.

The task of annulling such a contract, when once made, is no child's play, and would make a terrific commotion. If we tie ourselves down to a particular steel this contingency is almost sure to happen, but if the wire drawer can use any steel he pleases, this contingency can scarcely arise.

I know of no wire drawer who, with open eyes, will bind himself to use another man's steel exclusively ; and it is for this reason that the outside gentlemen are so anxious to put in independent bids, and then trust to luck to get somebody to draw the wire for them.

For seven long years past our gradually rising towers have warned all interested parties that our cable-wire would be wanted at an early day, and now, when the time has come, they are not ready, but want to hedge around in some irregular way to get an advantage over the rest, and I am free to tell you that I shall use my utmost influence against any irregular bid, because I look upon them as made with deliberate attempt to get an unfair advantage over fair and square bidders.

I can give no better illustration of the foregoing points than by referring to the contract for Bridge ropes, now being executed at Trenton Here were a number of ropes to be made in accordance with a set of strict specifications, but, in addition, they had to be made out of a particular kind of steel, and these two conditions proved antagonistic.

Many months of time and labor were expended in vain attempts to make it answer, and when finally enough had been squeezed out to pass the tests for one or two ropes, it was still found to show such a want of uniformity, and be so full of inherent defects, as to break of its own accord when laid up in the rope.

Now, here was material which was manifestly unfit to be put into ropes, notwithstanding it had passed the tests as steel. The question, therefore, at once arose, should we go on and make poor ropes, and remain within the letter of the law, or throw it to one side and use a material suitable for the purpose?

The large quantity of condemned chrome steel now lying in the mill yard, shows which way this decision went.

I need only say, in conclusion, that I am opposed to any bid which does not come from a *wire* maker of good reputation, and long experience in making steel wire.

Our great necessity is for steel wire of perfect uniformity. If a wire breaks during cable-making, we always lose two wires of the whole length of the cables, valued, say, at $10. The regulation of the wires back of them may be disturbed, so that the loss of time is in no case less than two hours, and often a whole day, during which time nothing can be done, and the whole work stops. In such a case we would lose from two to three hundred dollars.

Very truly yours,

W A. Roebling."

CABLE WIRE SPECIFICATIONS.

At the time these cable-wire specifications were written, I supposed, in common with other engineers, in fact it was in accordance with all the tests I had made up to that time, that Open Hearth or Bessemer steel could not be made to come up to the standard required.

The whole specifications were written in accordance with these views. Bessemer and Open Hearth steels were carefully excluded, and only crucible cast-steel called for, and the specifications were so submitted to the Trustees. After due discussion in their Board, it was decided to enlarge the field of competition, by receiving bids from all kinds of steel wire makers, and not limit them to crucible cast steel. In this shape the specifications were put before the public.

After the issue of the specifications, three months of incessant activity ensued among such wire drawers as intended to bid on the work. It soon became manifest, from samples received, that both Open Hearth and Bessemer steels could be so manipulated as to meet the requirements in every respect, giving a *uniformity* equal to and even superior to any brand of cast-steel, and this could be done not only in a few specimen rings, but in many tons at a time.

To what extent this may be due to the making of the steel or to the drawing of the wire I am not prepared to say, but inasmuch as several kinds of Bessemer steel produced nearly the same results, it is probably largely due to the wire drawing.

Now this is a very important fact, not only in its bearing on steel wire in general, but particularly its effect on the cost of the bridge and cables, because Open Hearth or Bessemer wire can be made at a cost approximating one half the price of good cast-steel wire, and the saving of two or three hundred thousand dollars is a matter of no small moment to the two cities.

It was supposed at the time of writing these specifications that such wire as was called for could not be made without going through the process of hardening and tempering. The tests of the final sample, however, showed that all the requirements could be met, without subjecting the wire to this process. This is largely due to the size of wire used, and has resulted in a considerable diminution of the amount of each bid.

STRAIGHTENING THE WIRE.

In regard to the subject of straightening of the wire, it should be said that this idea was perfected by Col. Paine only a short time previous to the issue of the specifications, the bulk of the preliminary tests having been made with ordinary curved wire.

As the difference of curvature between the inside and outside of a ring of wire, two feet in diameter, is considerable, it may readily be supposed that the metal is in different conditions of strain, on the two respective sides. The elimination of such strain is not only perfectly accomplished by this process of straightening, but it involves other results of great importance. Both the ultimate strength and the limit of elasticity are raised nearly eight per cent., but the modulus was uniformly found to be as high as 29,000,000.

If time had allowed of making the experimental tests solely with straight wire, the modulus would have been fixed at 29,000,000 and above, instead of allowing a margin, as has been done. The apparent anomaly of calling for a stretch of two per cent. in the 50 feet lengths, and $3\frac{1}{2}$ per cent. in the 5 feet lengths, where the reverse might be expected, is susceptible of an easy explanation. No wire under strain breaks in two places at the same time. As soon as the strain has passed the limits of elasticity, weak places begin to develop themselves at particular points, and a greater portion of the stretch is thenceforth confined to their immediate neighborhood, and not distributed over the whole length of the wire. The percentage of stretch when referred to the long length must therefore be less than when referred to the short length. This also explains the fact why the same piece of wire when broken a second or third time will exhibit the same or often a greater strength than when broken the first time.

APPROACHES.

As cable-making will be under fair headway by next spring, the time will then have arrived to commence actual work on the construction of our approaches.

We cannot, of course, commence on the whole line at once, and it will be most convenient to commence at each of the anchorages, and work towards the termini.

Last spring one of the assistant engineers, Mr. Hildenbrand, was instructed to make several alternative designs, principally in reference to the appearance of the side elevation of the New York approach. He also made four different plans for the bridge across Franklin Square.

As the side elevations will, in all probability, front on an important street in New York, it is, perhaps, fitting that the architectural features on that side should be of a better character, and of more imposing appearance than on the Brooklyn side, where the approach is not so much exposed to view.

BROOKLYN APPROACH.

Commencing at York street, there will have to be erected on each side of the street two lofty, substantial parallel walls, for the purpose of supporting the six "plate-girders" by which the approach crosses York street, in an oblique direction. In order to adapt the walls for future use in forming the sides of buildings, they will be provided with suitable archways to serve as doors and windows. Where Garrison street enters York, a wrought iron girder must be thrown across the end of the former, as a support for the main girder crossing York street.

The space of ground between the wall on York street and the rear of the anchorage can, of course, be occupied. In this discussion the primary object of this construction should not be lost sight of, which is to support the roadway of the approach, and every other consideration must be subordinate to it. Owing to the height at this point, such support can only be in the nature of columns; either isolated iron columns, or brick piers connected by light longitudinal arches. To give the necessary lateral support to such columns they must be enclosed by walls with substantial buttresses, which form the side view of the architectural drawings now being made. These remarks apply also to that part of the approach between York and Main streets, though it may be desirable to make it of a more imposing architectural character, or similar to the approach on the New York side, described further on.

As soon as Main street is passed we come to that part of the approach bounded by Prospect and Main streets, on which will be located the machinery that will drive the endless ropes for the trains on the railroad tracks. Here the supports must be arranged to suit that object. The large square at the terminus can either be filled up solid with earth or be arranged for an underground depot or station, if required.

I do not think it advisable that we should at once make all the necessary preparations for establishing warehouses under this approach, but confine ourselves to what is needed for support merely.

The uses to which these spaces can be put are, after all, quite limited. The incessant rumbling overhead is one serious objection to them. The necessary amount of light will be difficult to obtain. No chimneys can pierce the roof, but must come out on the outer walls. They could, however, be heated by steam. Many other objections to them might be mentioned, all of which goes to show that the utilization of these spaces had better be left until the approach is finished, or until the demands of trade indicate clearly what is required.

To commence work, therefore, next season, it is necessary to obtain possession of the following property: The property on James street, including the whole of the triangular cluster of old frame buildings bounded by York, James and Main streets, and James street closed. It will also be necessary to purchase the north corner of Garrison and York streets.

NEW YORK APPROACH.

This approach differs in many particulars from that of Brooklyn. It is nearly twice as long, and much more elevated, thus involving more cost and labor in construction. Its location also demands more of an architectural display than can be made in Brooklyn.

The property between the anchorage and Franklin Square we own already and it gives room for one building. The location is very desirable for business purposes, hence I think it would be well in this instance to adapt the building to business purposes at once, and the inner division walls as well as the outer ones can be constructed in accordance with plans made for that purpose. A portion of the interior of this building can also be devoted to stairways for the purpose of gaining access to the top of the anchorage, whence people can cross the bridge on foot or take the horse cars. The front of this building on Cherry street must, of course, consist of heavy walls supporting one end of the bridge by which the approach crosses Franklin Square.

The Franklin Square bridge will be 85 feet wide; 195 feet long at the north end, and about 140 feet long at the south side. Four general styles of structure are possible at this point:

First, the stone arch.

Second, the wrought or cast iron arch.

Third, a girder crossing the whole span.

Fourth, a girder supported in the middle by two cross girders resting on one column on the south side, and two on the north side. This arrangement practically divides the span into two bridges, one over Pearl street and the other over Cherry street.

The relative cost of these bridges is about in the order in which they are enumerated. The stone arch will cost about five or six times as much as the others; the material itself is costly, the abutments would be extremely massive, and contain large quantities of material, chiefly because the foundations have to go down as low as the anchorage in order to insure the necessary stability. The heavy centering on which to support these arches is also expensive, and would tend to obstruct the two streets These same remarks would apply with much less force, however, to the iron arches.

A continuous girder across the whole span is cheaper than the two previous arrangements, but it is more expensive than that supported by the columns. The length of the span would require a truss of sixteen or eighteen feet in height. This would not look well in that situation, as it would obstruct the view up and down the street too much; besides, two of these girders on the north side would only be elevated a foot or two above the lowered roof of the building between Cherry and

Pearl streets, which would look odd—almost absurd—in such a locality.

The last of the four plans (which might be called the column plan), will be the cheapest and will also look very well. This calls for a cast-iron column, or rather cluster of columns, at the point between Cherry and Pearl streets, and for two brick piers, to be erected within the walls of the building between these two streets. On these supports rest two transverse wrought iron girders, which latter support the main bridge.

A single or double Warren girder about nine feet in depth will make the best kind of truss. With the central support it can be calculated as a continuous girder, thus requiring a minimum amount of iron. The roadway of the bridge will rest on top of these girders.

The stone abutments at each end will also contain less masonry than by any other plan.

The bridges over all the other streets will be ordinary plate girders.

We come now to the question of opening a street parallel to the south side of this approach.

The location of Frankfort street, with reference to the approach, is such that it of itself forms such a street for the greater part of the distance. In any way that the question can be discussed, the inevitable conclusion is forced upon us that such a street should be established. Even outside of the Bridge question, the necessity for such a street is apparent, because there is not a single wide street leading from the vicinity of the City Hall straight down to the East river, below New Chambers street. The extra amount of property required is but little. One or two lots between Franklin Square and Cliff street, and a portion of Burr's building, on the corner of Cliff and Frankfort streets. By this plan the lower end of the present Frankfort street, from Cliff to Pearl, will be closed. The steep grade near Vandewater street can also be diminished to the extent of two or three feet.

Respecting the question of an alley of from twelve to sixteen feet wide on the north side of the approach, two points have to be decided. If the property underneath is to be utilized now, then this alley should be opened at once; but if not, there can be no immediate necessity for it. In either case the positions of the lots we cut through are such that we have to buy half the land required for an alley.

The wall on the north side of the approach can be made of a plainer character than that on Frankfort street. Each space beneath the approach will be included within four walls, two of them forming the principal sides of the approach, and two forming the abutments for the girders across the streets. Within this space suitable supports for the roadway will be constructed. Estimates are now being made to determine as to whether iron columns, suitably braced, or brick piers with connecting arches, will best answer the purpose. The supports will be so arranged as to facilitate the division of the future warehouses into stories.

The utilization of these spaces will be effected at a much earlier day than on the Brooklyn side.

In order to illustrate the plan of brick piers and arches, let us take the block between Cliff and Vandewater streets. This represents a rectangle 85 feet wide by about 250 feet in length, and surrounded on all four sides by walls: at the narrow ends by the abutment walls, and at the two other sides by the main walls of the approach. Within this space there will be carried up three or four longitudinal parallel rows of brick piers, from fifteen to eighteen feet apart, and connected together by light flying arches. The dimensions of the piers at the base would be about six feet, and tapering off to about three feet at the summit The offsets in the piers as well as the connecting arches can be made suitable for division into stories. The connecting arches will be only about eighteen inches in thickness at the crown, and of a uniform width with the piers.

The top will be covered by a coping of stone or cast-iron. Laterally, these brick piers must be braced by heavy iron beams, twelve or fifteen inches deep. These can be so placed as to serve as supports for the floors of the different stories.

The general arrangement above described comes the nearest to being fire-proof of any that can be devised, although it may prove a little more expensive than that with iron columns alone.

The roof, in any case, will be formed by laying iron beams across the longitudinal walls and connecting them into a solid platform by short, brick arches, in the manner ordinarily pursued in fire-proof structures. The roadway on this platform must follow the same general arrangement as on the main bridge. The horse car rails with the iron tramways alongside for wagon wheels will be continued through. These rails and irons will be secured to longitudinal wooden sleepers, which latter are fastened to the iron beams underneath. Wood is required to give the necessary elasticity, and if properly prepared will last a long time. The central space in each tramway, where the horses walk, must be filled with a suitable pavement, probably of wooden blocks, which, in such a place, will be very durable, for the reason that the causes which usually wear out wooden pavements are not found here, as it is well drained by the slope; the frost will not upheave it, and since it will not have to be taken up for any purpose, it will wear evenly all over. The space between the tramways can be filled in with asphalt or concrete.

Under the principal railway tracks where the passenger trains run, we have the option to leave the spaces between open or closed. If left open they will furnish light for the spaces underneath, which otherwise must come from the distant end walls; but, on the other hand, a separate roof would be required underneath to carry off the rain; hence, if these spaces are not to be utilized at once it may be as well to close them; either way is immaterial, as far as the track is concerned.

The trains of passenger cars will be from 400 to 500 feet in length. The floor of such a car from two and a half to three feet above the track, hence the platform on which the passengers stand, must be at the same height above the track for the distance already given. This will take in a greater portion of the Brooklyn approach, and about one-third of the New York approach. It will therefore be advisable to continue the central sidewalk at this elevation over the remainder of the New York approach until it passes the anchorages. We thus avoid two awkward sets of steps up and down. This height of three feet also affords an opportunity of putting in side lights along the central platform, and thus lighting the place underneath, even if the railroad tracks are closed up tight.

As to the material of which this platform should be made, I prefer yellow pine planking to stone flagging; planking is more pleasant to walk on, does not get slippery in freezing weather like stone, which is quite a consideration on account of the grade; it can be easily repaired piece by piece without interrupting the whole travel, as would be the case when replacing flagging. At the ends of the approaches, between Chatham and William streets, and Sands and Prospect streets, the spaces will be covered with regular pavement.

All the bridges at the street crossings will be plate girders except the Franklin Square bridge and the crossings at William and North William streets, where solid brick arches may be preferable, provided we have the necessary head room underneath.

Between North William and Chatham streets there will be required an underground room for holding the return wheels of the propelling ropes and the sliding frames for tightening the latter.

A brief recapitulation of the foregoing remarks goes to show that all the questions involved in this approach are pretty well settled except one ; which is the manner of supporting the roadway of the approach. Either of the two methods proposed are adequate as far as the mere supporting power is concerned. The plan of wrought iron columns will probably be a little cheaper as regards first cost, but independent of price the plan of brick arches and piers has so many considerations in its favor that it should, on the whole, be adopted. Brick piers can be erected with equal rapidity, will be more substantial and permanent in their character, and absolutely resist the action of fire, whilst iron columns do not. The manner in which the division and surrounding walls will be tied together gives also a greater stability to the whole structure, besides furnishing one great step towards future utilization.

Foundations for the walls of the approach must be of various characters, according to the nature of the ground. In the "Swamp" piles must be driven ; in the sand we can make concrete foundations; and in more compact ground ordinary rubble walls will answer, with broad flat stones for footings.

The foundation walls and brick arches resting against the rear of the anchorage will add a little weight thereon, which is not undesirable.

The amount of work required to perfect the drawings for the details of these approaches—involving, as it does, designs for a series of structures a quarter of a mile long—is very great. Fortunately we have in Mr. Hildenbrand an architect both by profession and practice. The Grand Central Depot was built from drawings made by him, and his designs for the International Exhibition building show great capacity. Since his release from the duties of stone inspection, Mr. Vanderbosch has also rendered very able and efficient aid in making these designs, a work which comes in the line of his profession.

In conclusion, I must express my satisfaction and appreciation of the services rendered by the gentlemen who have assisted me thus far in the construction of the various parts of this work. Owing to my prolonged illness and consequent enforced absence, the actual execution of the work has largely devolved upon my assistants. As Engineer in charge, Mr. Martin has had a general superintendence of the whole work, which he has done in his usual faithful and energetic manner.

Col. Paine, in addition to completing the New York tower, has attended to all the details connected with the work and tests incident to the wire ropes and the cable-wire, a task for which he has shown a special aptitude. He has given to this subject an untiring application, united with a spirit of patient investigation, which takes nothing for granted, resulting in new and valuable discoveries and improvements.

Mr. Collingwood has had charge of the New York anchorage for the past two years, and has conducted this work to a successful completion in the most able and efficient manner, and in a remarkably short space of time.

Mr. McNulty successfully completed the Brooklyn anchorage, since which time he has been employed in the office making plans and designs for different parts of the work.

Mr. Hildenbrand, of whose ability as an architect I have already spoken in my remarks about the approaches, is the repository of most of the calculations and plans pertaining to the superstructure of the Bridge.

Mr. Farrington, of whom I have spoken in connection with the foot-bridge, will, after its completion, continue in immediate charge of cable-making.

All of the more important specifications for materials issued during the past two years, together with the reports upon tests of steel wire recently submitted to the Board of Trustees, will be found in the appendix to this report.

Below is given the revised estimate brought up to January, 1877, showing the total cost of the work and the expenditure yet to be made to complete it.

Respectfully yours,

W. A. ROEBLING,

Engineer.

ESTIMATE OF JANUARY 1st, 1877.

Amount required to complete the Brooklyn tower		$7,000.00
Amount required to complete the New York tower.....		14,778.00
Amount required to complele the Brooklyn anchorage.		56,948.41
Amount required to complete the New York anchorage.		59,552.41
Suspended superstructure, original......	$3,011,010.00	
Expended during 1876......................	94,056.42	
Suspended superstructure, amount yet to be expended		2.916,953.58
Approaches....		742,516.00
Toll Houses and gateways..........		20.000.00
Engineering (unexpended balance)........................		108,886.76
Contingencies (unexpended balance)........................		93,957.49
Am't required to complete the Bridge and approaches.		4,020,592.65
Land yet to be taken (unexpended balance)...............		2,267,381.76
Amount yet to be expended for land, and to complete the structure...		6,287,974.41

WHOLE COST OF THE BRIDGE AS NOW ESTIMATED.

Amount thus far expended, as per Treasurer's statement..................	$7,059,808.49	
Deduct receipts for rents, wharfage and material sold.......................	164,896.41	
	$6,894,912.08	
Add liabilities on January 1, 1877........	15,304.75	
Net expenditure, as per Treasr's books.	$6,910,216.83	
Deduct material, etc., on hand, as per inventories..................................	82,064.92	
Total net expenditures to January 1, 1877............		6.828,151.91
Total cost by present estimate..........................		$13,116,126.32

APPENDIX.

I.

SPECIFICATIONS.

SPECIFICATIONS FOR GRANITE FACE-STONE AND ARCH-STONE, REQUIRED FOR THE NEW YORK TOWER, EAST RIVER BRIDGE, APRIL, 1875.

1. Proposals are invited up to April 15th, 1875, for the delivery of 6,056 cubic yards of cut Face-stone, Archstone and Dimension-backing, from and including the fourth course above springing line of arch to the coping, comprising a height of 68 feet.

2. An inspection of the plan shows three solid vertical shafts of a cruciform section, extending from the fourth arch-course to the upper cornice, and having a height of 46 feet.

3. Above this is the upper cornice, extending across the whole width of the Tower, having a total height of about 22 feet, and comprising two diamond beads with a necking between; an outward sloping section about 9 feet high, a square cap course, and the coping and lower roof-stone forming the roof of the Tower.

4. The three vertical shafts are connected by two pointed arches which have a rise of 35 feet 6 inches; a span of 33 feet 9 inches, and a width of 21 feet.

5. These arches consist of 18 ring-stones on each side, surmounted by a key-stone.

Above the arch is the spandrel-filling of varying thickness of courses, and covered by a broad band-course at the line of the key-stone. The space between the key-stone and the cornice is occupied by a recessed panel.

6. The interior space above the spandrel-filling is not all solid, but consists of three parallel walls, separated by two hollow spaces. The middle wall is 4 feet 2 inches thick, the two outer ones vary from 4 feet 2 inches to 5 feet 3 inches in thickness, and the width of the hollow spaces varies from 4 feet 3 inches to 4 feet 9 inches.

7. In order to maintain communication with the roof of the Tower, a hole is built into the masonry on the south side, commencing at the second arch-course, extending through the spandrel-filling into the hollow

spaces above the arch, and opening out upon the roof through a trap-door.

8. A detailed plan on the scale of five feet to the inch will be furnished for all the regular courses, as well as for the Arch-stone and spandrels, giving the exact dimension, location, and denomination of each stone, and an isometrical projection where necessary.

The plan of bond must be in every case adhered to.

Templates will be furnished for each Arch-stone.

9. The rises will vary in the main from 22 to 30 inches. They will be fixed on the plan of every course.

CHARACTER OF CUTTING IN THE DIFFERENT SECTIONS OF MASONRY.

10. The Face-stone of the buttresses in the vertical sections will all be rock-face, with a draft cut all around the face $1\frac{1}{2}$ inches wide.

The appearance of the stone will be that of subdued rock-face, the projections not to exceed 3 inches.

No special pains need be taken with this rock-face, the idea simply being to have it less bold than that below the floor. It will not be required that the rock-face shall be leveled off to one uniform face 3 inches high, but merely that the projection shall not exceed 3 inches.

11. Since the draft-line extends around the four edges of the face of every stone, it follows that all the outer as well as the inner angles of the buttresses will have a clear vertical draft of $1\frac{1}{2}$ inches wide.

The color of the stone is immaterial, but it must be granite, of good clear stock.

12. The outward slope of the upper cornice will be cut precisely like the one in the cornice below the floor.

Each stone has a draft-line of $1\frac{1}{2}$ inches wide all around the face, and the face itself is pointed down to a uniform projection of about $\frac{1}{2}$ an inch.

The color of the cornice stone must be light, so as to form a contrast with the darker buttress stone.

13. Square openings are left in the sloping part of the upper cornice for the passage of the cables.

ARCH-STONE.

14. The number and dimensions of the Arch-stones are given in the plans. It will be noticed that the lower Arch-stones are not alike on each side, owing to the fact that the arch is not symmetrical with the centre lines of outer and middle buttresses. It will also be observed that the extrados and intrados do not form concentric curves, but that the Arch-stones become smaller as they approach the vertex.

15. The face of the outer ring-stone of the arch will be cut with a draft all around the five edges. This draft will be three inches wide along the curved edge (intrados), two inches wide along the two adjoining edges

(lower and upper bed), two inches wide along the upper horizontal bed, and 2 inches wide along the vertical edge.

The face within the draft will be cut down to a uniform projection $1\frac{1}{2}$ inches high. This inner face is simply rough-pointed to a uniform level, but without plug-holes.

The intrados, or inner facing of the Arch-stone, will be pointed down smooth, or else rough-axed or peen-hammered. The cutting need not be fine, but no plug-holes are admissible.

16. It will be noticed that the Arch-stones are cut on all faces.

Patterns will be furnished of full size for each Arch-stone and detail-drawings given on a large scale, with the exact dimensions. In these patterns as well as in the detail-drawings, allowance is already made for joints, hence the stones must be cut exactly to the patterns or given dimensions.

The upper corner of each ring-stone is a right angle; a horizontal bed is thus formed for the spandrel course above to rest on. Moreover, owing to the different curvature of the extrados and intrados, the radial joints all differ in length, being 1 foot deeper at the springing line of the arch than at the key-stone, the former depth being 5 feet and the latter 4 feet.

The courses of ring-stones are bonded among themselves, the alternate courses containing respectively 4 and 5 stones.

17. Reference has already been made to the hole in the masonry on the south side. It is 3 feet by 2 feet 5 inches, and passes up vertically and inclined, coming out in the hollow space above the arch. Its course is accurately traced in all the plans, and care must be taken that all stones facing it, Face-stones as well as dimension-backing, do not lack in width or length, and are nicely squared-off.

18. The key-stone forms a pointed wedge, 7 feet $6\frac{3}{4}$ inches high and 5 feet $\frac{1}{2}$ inch wide.

It projects 13 inches beyond the face of the arch, and care must therefore be taken that the projecting part is cut as fine as the face. This latter consists of two raised panels each 2 inches high, separated from the outer edges of the stone and from each other respectively by 7-inch draft-lines along the sides and 9-inch draft-lines along the upper edges. The projecting panels are sloped on the upper side to shed water.

The whole face of the key-stone, panels and drafts, is 6-cut work. There are four pieces of front key-stone. The inner key-stones, six in number, are cut after the same pattern, but only 5 feet $6\frac{3}{4}$ inches high, and no other work put on them than good pointed beds and builds, not lacking in any dimension, and having none or only small plug-holes.

SPANDREL-COURSES.

19. In place of projecting the ring-stone beyond the face of the spandrel-courses, as is usually done, the reversed plan is adopted.

The lowest spandrel-course will project $\frac{1}{2}$ inch, each succeeding one $\frac{1}{2}$

inch more, so that the upper spandrel-course below the key-stone projects 7½ inches beyond the face of the arch.

20. The top spandrel, or band-course, in range with the key-stone, projects, in addition, 2½ inches more, making 10 inches in all beyond the face of the arch.

This band-course will be 30 inches high, and the projecting part of its top-bed will be sloped down 2 inches to form a water-shed.

The two double-headers in the middle buttress of this course will have the figures "1875" cut on their faces. In order to make these prominent, a raised panel 3 inches high, 25 inches wide, and 6 feet 9 inches long, with a draft-line 2¼ inches wide all around, will be cut on the face. What remains of the stone is rock-face, as usual with 1½ inch drafts on the three sides. From this raised panel, which must be smooth eight or ten cut-work, the figures project, in addition, 3 inches more. They are about 21 inches high and 4 inches broad, and their exact shape, position and size, will be given in a full-sized drawing. The upper face of these figures must be highly *polished*, so as to form a dark contrast against the white back-ground of the panel.

21. The face of the spandrel-courses will be cut without drafts, either horizontal or vertical, and will be pointed down to a uniform surface, a little finer than the pointed work of the sloping offsets, and without plug-holes on the face, but not near as fine as 6-cut work.

The spandrels should convey the idea of one stone extending from the buttress to the Arch-stone; hence the intermediate vertical joints must be worked close and snug.

22. The band-course has horizontal drafts 3 inches wide. Next to key-stone and buttress, it has vertical drafts 9 inches wide. The intermediate vertical joints have no drafts. The raised panel formed by the drafts is 2 inches high, its face being pointed work. Along its upper edge it is sloped to shed water. Care must be taken that this panel comes clear out to the intermediate joints, with sharp and unbroken edges.

This stone must be of a light color.

23. It will be noticed that the thickness of the spandrels decreases as we go up.

The thickness of the buttress-courses likewise diminishes to the fifth course below the band-course. From here on, the buttress-courses are uniform, whereas the spandrel-courses are notched out to form the bond.

There is, consequently, one more spandrel than buttress-course; it is called 135½th course.

24. The courses above the band-course, six in number, form what is called the recessed panel, because they step 10 inches back from the face of the band-course, ranging plumb with the general face of the arch. Their rises are the same as the adjacent buttress-stone with which they bond in.

Each stone will have a horizontal draft of 1½ inches, and in the corners next to the buttresses there will be a vertical draft 9 inches wide. Between the draft is subdued rock-face, projecting not more than 2 inches. This horizontal draft is continuous between the buttresses, and hence the vertical joints have no draft.

PARALLEL WALLS.

25. Above the upper line of the key-stone the filling above the arches is no longer solid, but will consist of three parallel walls, inclosing two parallel hollow spaces of the sizes given in § 6.

The centre wall will consist of a single stone 4 feet 2 inches wide, of varying length, to break joint, with an occasional binder reaching across the space to tie the walls together. At a point 4 feet above the arch-filling there is a hole in the middle wall 2 feet by 4 feet to connect the hollow spaces. The stones of this middle wall are considered as dimension-backing, but where they face the hollow spaces rock-face will be allowed. The same holds true for the rear of the face-stones which face the hollow spaces.

UPPER CORNICE.

26. This consists of light-colored stone throughout. The lowest section, which comprises two diamond beads of 16½ inches high each, with a smooth necking or band of 29 inches between. It extends around the entire tower. The cutting will be 6-cut work like the coping, without draft of any kind, except the sloping portion above upper bead, which will have a 1½ inch draft around it, and be pointed down to ½ inch projection, and the portion below the lower bead, which will have a 1½ inch draft around it and be rock-face.

27. The outward slope is about 9 feet high, and also extends around the whole Tower. The face of each stone has a draft line of 1½ inches all around the four edges: and the panel within is pointed work of about ½ inch uniform projection. Where the rear face of these stones faces the hollow spaces it can be rock-face; but where it joints dimension-backing it must be cut true and plumb like the latter.

28. Openings are left in these courses in the buttresses for the passage of the main cables. These openings are square on the external face, but enlarge inwardly towards the saddle-plates. The inner faces of the stone in these openings will be cut vertical, and must be rough-axed or rough-pointed, but without plug-holes.

29. Above the slope is the square cap-course projecting 1 foot, and extending over the entire Tower, thereby covering the hollow spaces. It is 24 inches high, consists in the main of large stones, and must be 6-cut work.

The coping and lower roof-stone above are in two courses, and extend over the whole space, with the exception of the saddles, where an uncovered space is left. The face of the cap and coping-stone is smooth 6-cut work, like the lower coping at the floor-line.

The projecting squ re cap course will have a water-drip cut in its lower bed 2 inches from the outer edge, and being $1\frac{1}{2}$ inches wide by 1 inch deep.

The upper roof-stones are cut on the upper surface according to the various slopes and lines corresponding to the lines of the water-shed and the buttresses, as shown on the plan. The cutting will be smooth 6-cut work like the face. All joints must be cut close and true.

DIMENSION-BACKING.

30. All dimension-backing must be cut exactly to the size given on the plans, as allowance for joints is already made in these figures. The beds and builds must be of the usual quality, and the sides must be cut square and true, or, if not square, exactly to the angle given on the plan. The greatest pressure comes under the saddle-plates; hence special care must be taken that all dimension-backing under the saddles for four courses below—that is, from 151st to 147th course—are perfectly sound, without crack or flaw. Those directly under the saddle-plates shall have no plug-holes whatever, neither in lower nor upper bed. These are the stones: Nos. 49, 51, 52, 53, 54, 61, 62, 63, 64, 65, 66, 67, 74, 75, 76, 77 and 78, of dimension-backing, and Nos. 41, 44, 48, 32, 36, 20, 24 and 27, of face-stones of 151st course. The outlines of the saddle-plates are traced on the plan in blue lines, so as to show which portion of the face-stone must be free from any plug-hole. All the above-named stones, besides Nos. 3, 8, 12 and 17 must be cut exact to dimension and be square and true in order to make close joints.

REMARKS ON THE CUTTING OF THE STONE.

31. The upper and lower beds of all face-stone and dimension-backing must be rough-axed and cut true and parallel to each other, as well as square to the face where the work is plumb.

The bedding must be sufficiently true and even for $\frac{1}{2}$-inch joints. It must bear the straight-edge all over, but need not be fine. Square and parallel cutting of beds will be insisted upon. No hollow or slack cutting, or falling away towards the rear of the bed, will be permitted.

The vertical joints of each stone must be sufficiently true to make $\frac{1}{2}$-inch joints. They must be cut square with the face of the stone for a distance back equal to the width of the bed of the adjacent stretcher. Beyond that the side and rear faces may be left rough, in case they adjoin common backing. But where they join dimension-backing all faces must be throughout plumb and true.

32. In regard to the dimensions of the stones the following remarks shall be noticed:

All stones shall be cut full to the rise given in the plan, except otherwise stated thereon.

Each Face-stone must be cut $\frac{1}{4}$ inch short in width or length for each face-joint between themselves, but must have full width and length when they join dimension-backing or other Face-stone inside the wall, because in the latter two cases allowance is already made.

Arch-stone and dimension-backing must be cut exactly to the patterns for the one and to the given dimensions for the other. All face Arch-stone will be cut $\frac{1}{4}$ inch short in width, and all middle Arch-stone $\frac{1}{2}$ inch.

The given figures never include raised panels or rock-face, but give only the distance between the edges of the drafts.

To illustrate the above by an example, some stones of the 133d course shall be nearer described, as follows:

No. 1, marked 3 feet 3 inches by 7 feet 1 inch, must be cut 3 feet $2\frac{3}{4}$ inches by 7 feet $\frac{3}{4}$ inches. No. 2, marked 4 feet by 7 feet 1 inch, must be cut 3 feet $11\frac{1}{2}$ inches by 7 feet $\frac{3}{4}$ inches.

No. 4, marked 10 feet 6 inches by 3 feet 6 inches, to be cut 10 feet 6 inches by 3 feet $5\frac{1}{4}$ inches.

No. 5, marked 9 feet by 3 feet 6 inches, to be cut about 9 feet by not less than 3 feet 6 inches, with a face of 5 feet 9 inches.

No. 6, marked 3 feet 3 inches by 9 feet 4 inches, to be cut 3 feet $2\frac{1}{4}$ inches by 9 feet 4 inches.

No. 7. Arch-stone, marked 3 feet 9 inches wide, to be cut 3 feet $8\frac{3}{4}$ inches without the panel; together with the panel the whole width will be 3 feet $10\frac{1}{4}$ inches.

No. 8, Arch-stone, marked 4 feet 8 inches wide, to be cut 4 feet $7\frac{1}{2}$ inches wide.

No. 47, marked 3 feet 3 inches by 8 feet $5\frac{3}{4}$ inches, to be cut 3 feet 3 inches by 8 feet $5\frac{3}{4}$ inches exactly.

No. 25, marked 10 feet by 3 feet 6 inches, to be cut 10 feet by 3 feet $5\frac{1}{4}$ inches.

No. 79, marked 3 feet by 8 feet $5\frac{3}{4}$ inches, to be cut these figures exactly.

33. In every case the best bed of the stone must be the bottom bed.

No plug-holes will be allowed more than 9 inches in diameter and $1\frac{1}{2}$ inches deep, and must not occupy more than one-fifth the area of the stone; they must not come within three inches of the outer edge. But in all stones directly under the saddle-plates, as already stated, no plug-holes can be permitted. Unless the width of a stretcher is indicated in the plans, it is understood to be no less than one and one-half times the rise, and when the face and back are not parallel the average width must be no less than one and one-half times the rise.

The length of headers, if not stated on the plan, must be no less than three times the rise. Where there is dimension-backing, the width of the header must be uniform throughout, and the rear face cut square.

34. No common backing will be wanted. All Face-stones with a sharp arris must be boxed.

All stones must be properly lewised with a flat lewis, and a portion of the Arch-stone must have two lewis holes.

GENERAL REMARKS.

35. Steam-power and derricks for unloading vessels will be furnished by the Bridge Company.

The crews of the vessels must assist in the unloading; they must bring the stone under the arm of the derrick, and must attach the lewis to the hoisting-block, and furnish all the labor that is required on board the vessels.

36. The delivery to commence June 1, 1875, and the stones must be all delivered by Dec. 1st., 1875.

37. In case mistakes are made in the cutting of the stone, either in regard to their dimensions or in the character of their faces, beds and joints, different from the drawings and specifications, the contractor is hereby distinctly notified that such stone will be condemned, and must be replaced by a new one if there is time to send for it; and, if not, then the cutting of a new one will be done by the Bridge Company at the contractor's expense; and such cost of labor and detention will be deducted from the monthly estimate.

38. Monthly estimates will be made on or about the 10th day of each month for stone delivered during the previous month, deducting 15 per cent., which sum will be kept as a guarantee for the satisfactory performance of the contract, and will be paid in one month from the time the contract is complete, and it is understood that in all estimates the exact cubic contents of the stone when delivered will be taken and no more. In no case will the rock-face which projects beyond the draft-line be measured or paid for.

39. The Bridge Company reserves the right to reject any or all bids offered; and, in order to obviate the contingency of an excessive price, they further reserve the right to let the contract in two or more parts, if it should prove to their advantage so to do.

40. Proposals will be directed to the New York Bridge Company, 21 Water street, Brooklyn.

W. A. ROEBLING,
Chief Engineer New York Bridge Company.

QUANTITIES OF MASONRY.

[NOTE.—Stone having about the same quality of cutting are grouped together in brackets.]

	Cubic Yds.	Price per Yard.	Total.
Buttress Face-stone, draft-line..... }	1483		
Panel above arch....... .... }	331		
Outer slope of upper cornice......... }	566		
Spandrel-filling......................... }	270		
Band course............. .... }	70		
Necking and square course..........	317		
2 bead courses and low'r roof-course	467		
Upper Roof-stone or coping.........	370		
Arch-face stone......................... }	256		
Inner Arch-stone and in'r Keystone }	345		
4 Keystones............................ }	20		
Stones with figures "1875"...........	Two pieces.	Per piece	
Dimension backing.....................	1156		
Total	6056		

SPECIFICATIONS FOR GRANITE CUT STONE, REQUIRED FOR THE PARAPETS AT THE ROADWAY, BROOKLYN AND NEW YORK TOWERS, EAST RIVER BRIDGE.

1. Proposals are invited up to November 6, 1876, for the delivery of about 116 cubic yards of Granite Cut Stone for parapets on top of the cornice at the floor-line of the bridge towers.

2. The parapet has a height of 5 feet 4 inches, and an aggregate length of 446 feet, consisting of 164 single pieces, which vary in length from 5 feet to 11 feet, and in weight from $\frac{3}{4}$ to $2\frac{1}{2}$ tons.

3. The height is divided into three courses, called the base, the shaft and the cap.

The base consists of a stone 13 inches high and 18 inches wide, which is surmounted by a water-table 4 inches high, and a sloping back $2\frac{3}{4}$ inches. The vertical shaft has a height ef 2 feet 11 inches, and a width of $15\frac{1}{4}$ inches. In order to relieve the uniformity of this plain surface, rectangular panels are cut in, 5 inches deep. The height is 1 foot 7 inches, and their sides slope towards the rear, making the inner face only 1 foot 4 inches high. The different lengths of the panels will be given in the detail drawings.

The cap consists of a concave quarter oval $3\frac{3}{4}$ inches high, a square belt $6\frac{1}{4}$ inches high, and a water-shed 2 inches high, making a total height or thickness of 12 inches. At the belt or greatest projection it has a width of $20\frac{3}{4}$ inches, while the bottom bed is only 17 and the top face $15\frac{1}{4}$ inches wide; the latter dimension making it apparent that the water-shed must fall back $5\frac{1}{2}$ inches. The top face is not horizontal or parallel to the bottom bed, but slopes towards the rear $\frac{1}{2}$ inch, making the total height of the cap at the back face only $11\frac{1}{2}$ inches.

4. In order to drain the water, trapezoidal openings will be cut in the base at suitable places, fixed on the detail drawings. They are 2 inches high, 2 feet 2 inches long in front, and 1 foot 8 inches long in the rear.

5. As each stone will be held in place by dowels, the contractor is required to drill 4 holes in each stone belonging to the base and shaft; two in the bottom, and two or occasionally three in the top-bed. The cap-stones will require only two holes in the bottom bed. All holes in the base-stones and those in the bottom of the shaft-stones, must have a diameter of $1\frac{3}{4}$ inches. Those in the cap-stones and in the top-bed of shaft will be only $1\frac{1}{4}$ inches. The depth of the latter shall be 5 inches; of those in the bottom of base 9 inches, and of those in the top of base and bottom of shaft 8 inches.

It will be strictly required that all of these holes shall be drilled perfectly plumb.

6. Detail plans made to the scale of 2 inches to the foot will be furnished to the contractor, which will guide him in everything not described in this specification.

CHARACTER OF MATERIAL AND CUTTING.

7. The material used must be granite of clear stock, fine grain and light color, such as Mount Waldo, Blue Hill or Mount Desert Granite, or from East Boston quarry, on Fox Island.

No sap, or stones with knots, seams, flaws or iron will be admitted.

8. The cutting of all front faces, beds and side joints must be 6-cut work of best workmanship. The rear face can be pean-hammered work, but without any plug or drill-holes. All of the other faces must also be entirely free from plug-holes. All sides of the drain-holes in the base of the panels in the shaft, and of the concave rounding in the cap must also be best 6-cut work.

9. In the projecting part of the bottom of the cap, a water drip must be cut, commencing 1 inch from the edge, being triangular in shape, ½ inch wide by ½ inch deep, and running all around the parapet.

10. The dimensions, as given in the detail plans, must be strictly adhered to, and no variation from them whatever will be allowed, as the harmony of the whole depends on them.

11. Stones with inaccurate cutting, for instance, faces out of plumb or beds out of level, or insufficient working in the upper moulding, will be rejected. Also, stones with broken edges, or corners in any part of the face.

12. No lewis-holes will be allowed in the cap-stones.

13. All stones must be properly boxed and the edges protected.

GENERAL REMARKS.

14. Steam power and derricks for unloading vessels will be furnished by the Trustees of the Bridge. The crews of the vessels must assist in unloading; they must bring the stone under the boom of the derrick, and attach the chain to both stone and hoisting block; in short, do all the labor that is required on board the vessels.

15. All stones must be delivered at the stone-yard of the New York and Brooklyn Bridge, at the Brooklyn tower, on or before April 1st, 1877.

16. In case mistakes are made by the contractor in cutting the stone, or in case poor material or workmanship is furnished, contrary to this specification, such stone will be condemned and must be replaced by others at the expense of the contractor.

17. Payment will be made on the 10th of every month for all stone delivered during the previous month, 15 per cent. being deducted until the satisfactory fulfillment of the contract, when the contractor will be paid in full. Each shipment should comprise either the whole or the half of the parapet for one tower. The stone for the Brooklyn tower must be delivered first, and no stone for the New York tower will be paid for before all of the Brooklyn parapet has been delivered.

18. Bids may be made per lineal foot or per cubic yard. In the latter case it is understood, that only the exact contents of the stone will be paid for, from which, however, the sunken panels, the drain-holes and dowel-holes shall not be deducted.

19. The Trustees of the Bridge reserve the right to reject any or all bids offered.

20. Proposals must be directed to "The Trustees of the New York and Brooklyn Bridge," 21 Water street, Brooklyn.

W. A. ROEBLING,
Chief Engineer New York and Brooklyn Bridge.

SPECIFICATIONS FOR CUT FACESTONE AND BACKING, LIMESTONE AND GRANITE REQUIRED FOR THE NEW YORK ANCHORAGE, EAST RIVER BRIDGE, 1875.

1. Proposals will be received until 12 M., April 17th, 1875, for the delivery of 5,008 cubic yards Cut Face-stone and Archstone, all of Limestone; 5,987 yards Cut Backing, of Limestone or Granite; and for 294 yards Cut Face-stone, and 644 yards Dimension-backing, of Granite.

2. This quantity is comprised in twenty-five courses of Masonry, as follows:

No. of Course.	MARKED.	RISE.	Limestone Backing.	Limestone Facing.	Granite Dimension Backing.	Granite Corners.	TOTAL.
4...	4..	22 in...	529 yds...	— yds...	98 yds..	— yds...	627 yds.
5...	A...	26 "...	— " ...	30 " ...	146 " ...	— " ...	176 "
6...	B...	28 "...	— " ...	209 " ...	195 " ...	— ...	404 "
7...	C...	30 "...	7 " ...	161 " ...	205 " ...	— ...	373 "
8...	D...	26 "...	— " ...	227 " ...	— " ...	— ...	227 "
9..	E...	24 "...	21 " ...	229 " ...	— " ...	— ...	250 "
10...	F...	28 "...	119 " ...	264 " ...	— " ...	— ...	383 "
11...	G...	30 "...	391 " ..	256 " ...	— " ...	20 yds...	667 "
12...	H...	26 "...	— " ...	228 " ...	— " ...	16 " ...	244 "
13...	I...	24 "..	300 " ...	208 " ...	— " ...	16 " ...	524 "
14...	K...	22 "...	270 " ...	118 " ...	— " ...	14 " ...	402 "
15...	L...	26 "...	— " ..	227 " ...	— " ...	17 " ...	244 "
16...	M...	28 "...	334 " ...	245 " ...	— " ...	17 " ...	596 "
17...	N...	30 "...	354 " ...	261 " ...	— " ...	18 " ..	633 "
18...	O...	28 "...	316 " ...	244 " ...	— " ...	17 " ...	577 "
19...	P...	26 "...	319 " ...	188 " ...	— " ...	17 " ...	524 "
20...	Q..	26 "...	348 " ...	182 " ...	— " ...	16 " ...	546 "
21...	R...	22 "...	298 " ...	152 " ...	— " ...	14 " ...	464 "
22...	S...	30 "...	386 " ...	215 " ...	— " ...	18 " ...	619 "
23...	T...	26 "...	386 " ...	191 " ...	— " ...	16 " ...	593 "
24...	U...	24 "...	340 " ...	192 " ...	— " ...	15 " ...	547 "
25...	V...	24 "...	205 " ...	191 " ...	— " ...	15 " ...	411 "
26...	W...	26 "...	361 " ...	207 " ...	— " ...	16 " ...	584 "
27...	X...	28 "...	379 " ...	226 " ...	— " ...	17 " ...	622 "
28...	Y...	24 "...	324 " ...	190 " ...	— " ...	15 " ...	529 "
Arch-Stone.—		...	—	.. 127 Sheeting ... 40 Face.....	"	—	... 167 "
TOTALS.			5,987 yds.	5,008 yds.	644 yds,	294 yds.	11,933 yds.

RECAPITULATION.

Limestone Facing, proper	4,841 yards.	
" Arch end Facing	40 "	
" Archstone aside from end fencing	127 "	
Total Limestone Face-stone		5,008 yards.
Total Limestone or Granite Backing		5,987 "
Granite Dimension-backing	644 yards.	
Granite Corners	294 "	
Total Granite		938 yards.
Total stone to be furnished		11,933 yards.

3. Detail drawings on a scale of 5 feet to the inch will be furnished for every course. All of the Granite, and part of the Limestone, are dimension stone, and every such stone will be designated by a special number. Every dimension stone must be cut *full*, and *no* allowances made for joints, as this has already been done. The *bottom* bed is the one referred to in every case, and allowances for *projections*, or *batter*, must be made accordingly.

Stones having no special number, may vary in dimensions from those given on the plans; *provided* that the total lengths of wall faces are made up, and that the dimensions, as furnished, do not make it necessary to *change the bond.* With these restrictions, stretchers may range from 5 feet to 10 feet in length, and shall not be *less* than 2 feet 9 inches wide; and headers may range from 5 feet to 7½ feet in length, and shall not be less than 3 feet, or more than 3½ feet in width.

LIMESTONE MASONRY.

4. The Limestone shall be equal in quality to the Kingston Limestone, or the Lake Champlain Bluestone. All stone with dry or flinty seams, which split with frost, will be rejected.

5. Of this, all the Face-stone must be cut with a bold rock face. A small portion will have plumb faces, but the greater part must be cut with a batter of one-half inch to the foot rise; this will be indicated by a note on the plan in every case. The front edges will be pitched off to a line. No draft will be required except at the projecting angle of corner stones, on which there shall be a 1½ inch vertical draft on each face.

6. The upper and lower beds of each Face-stone, must be rough-axed, and cut true and parallel to each other; and where the work is plumb they are to be cut square to the face.

The stone must gauge full to the rise The bedding must be sufficiently true for half-inch joints. It must bear the straight-edge all over but the cutting need not be fine. Square and parallel cutting of the beds, will be insisted upon. No hollow or slack cutting, or falling away towards the rear of the bed will be permitted. No plug-holes will be allowed more than 9 inches in diameter, or more than 1½ inches deep, nor within one foot of each other, or of the edge of the stone.

7. The vertical joints of the stone must be cut sufficiently true to make half-inch joints. They must be cut square with the face, for a distance back of no less than two feet; and in a header the joints must be cut back full and square for the whole width of the adjoining stretcher. They must in all cases be perfectly plumb, and at right angles to the plane of the bed.

8. The rear faces of stretchers may be left rough as they are split from the quarry. It will not be insisted upon that they shall be parallel to the front faces, although it is preferred. Headers must run back full width for at least half their length; the tail may, however, be wider than the front, and their rear faces may be left as they come from the quarry.

9. The best bed of every description of stone must be the bottom bed, and the lewis-holes must be put in the top bed and not the bottom.

10. In each course there will be a tail bond at each re entrant angle of the masonry. When these stones are headers they must be long enough to make a good bond. In all cases they must be properly jointed back, and exposed portions of their faces left rock-face as on other Face-stone.

11. Courses A to F. inclusive, will have ten corner-stones in each, with a batter on two faces. Courses E and F will also have four corner-stones in each, with a batter on one face and the other face plumb; and four also with both faces plumb.

12. There are two semi-circular arches running through the rear portion of the masonry, having a length at the springing line of 33 feet 6½ inches, and a radius of intrados of 7 feet. They will have an average thickness of 2 feet 6 inches, and be laid up in 13 longitudinal courses.

The upper faces of these, or the extrados, may be left as they come from the quarry, with the exception of the ring-stones, at the two ends, which must be pointed off to allow of a half-inch joint. The ends and sides of each archstone must likewise be pointed to allow of half-inch joints.

The outer faces of the end archstones, and the faces of all forming the intrados, shall be rock-face, with a draft line 1½ inches wide cut entirely around each.

BACKING.

13. The backing may be either Limestone or Granite, and must be quarried in rectangular blocks, with even, parallel beds. Both beds will be dressed and rough-axed, so as to make joints of not more than half an inch. All four vertical sides must be good quarry splits, with no projection exceeding four inches. The sizes of blocks may vary from twenty to eighty cubic feet, the larger blocks being preferred.

The stone must be of good quality, sound and durable, free from all cracks and seams in any direction.

No plug-holes more than nine inches diameter, or more than one and a half inches deep, will be allowed; and at least three-fourths of the upper bed and the whole of the lower bed, must present a good, uniform bearing surface.

GRANITE MASONRY.

14. The Granite for the corners must be *white*—as white as the Concord or Hallowel Granite, or that from East Boston quarry, on Fox Island. It must be uniform in color, sound and durable, free from all cracks or weak spots, and without seams of any kind.

15. Every course above F has ten Granite corners. Each face of these has a four-inch projection, which is made by cutting a chamfer entirely around the face, except at a projecting corner, which is left square. The chamfers must be fine cut. The surface between the chamfers must be pointed to a uniform surface, and a 1½ inch chisel draft cut entirely around each face. Samples of the work can be seen at the anchorage.

The cutting of beds and joints shall be similar to that of other Face-stones, as described in sections 5, 6 and 8.

16. The Dimension-backing must be sound in every respect. The beds must be cut as described in sections 5, 6 and 8; and the sides, except at the points where rock-face is noted on the plans, must be cut square, vertical and true.

As these stones serve to distribute the pressure from the Anchor-plates, it is very important that care be taken in selecting and cutting them. Fine cutting is not required.

GENERAL PROVISIONS.

17. All stone, both face and backing, must have suitable lewis-holes. A sample lewis will be furnished to the contractor, and all holes must be cut so that it will fit properly, and allow the lewis to be inserted its full depth. No round lewis-holes will be permitted. All lewis-holes must be so placed that when the stones are suspended they will hang in proper position for setting.

18. The stones are to be delivered at the wharves of the Bridge Company at Red Hook.

Steam power, for unloading vessels, will be furnished by the Bridge Company, six unloading derricks being provided at the edge of the wharf. The crews of the vessels must assist in unloading. They must bring the stone under the boom of the derrick, and must attach the hoisting block to the lewis, and furnish all labor that is required on board the vessel for unloading as rapidly as the Bridge Company may require.

19. The first course of stone must be delivered by July 1st, and the balance at the rate of two courses per week, in the order of the numbers. As it is of the utmost importance that the delivery of the stone be prompt and in the order of the courses, this rate of delivery will be insisted upon; and if there are *delays* in the delivery, *from any cause whatever*, the stone will be obtained elsewhere, and the attendant expense will be charged to the contractor, together with all damages arising from delays.

20. Parties proposing must be known as men both skilled in the quarrying and cutting of stone, as well as prompt and reliable in their business transactions, and must bring satisfactory references to that effect, as well as to their financial responsibility.

21. In case any mistakes are made in the cutting of the stone, as regards the character of the beds or joints, or in the rise, or if there are other gross violations of the provisions of these specifications, the contractor is distinctly notified that such stone will be either wholly condemned and thrown back on his hands, or else a proportionate reduction in the price will be made, the same being at the option of the Engineer. Condemned Facestone will be reckoned as backing.

22. Any question as to the intent or meaning of these specifications shall be referred to the Engineer, whose decision shall be final.

23. The Bridge Company reserve to themselves the right to reject any or all bids offered, and to make awards of separate portions of the total quantities required, if to their interest so to do.

24. Bids will be received as follows:

LIMESTONE.

For	4,841	cubic yards Face-stone, delivered, per cubic yard......	$....
For	127	" Arch Sheeting, delivered, per cubic yard....	$....
For	40	" Arch Face-stone " "	$....

LIMESTONE OR GRANITE.

For	5,987	cubic yards cut Backing delivered, per cubic yard......	$....

GRANITE.

For	644	cubic yards Dimension-backing, delivered, per cubic yard..	$....
For	294	" Granite corners " " ..	$....

25. Monthly estimates will be made on or about the 10th day of each month for stone delivered during the previous month, provided that no stone will be estimated for until all courses below them are completed. Payments will be made on these estimates after deducting 15 per cent., said deduction to be kept as a guarantee for the satisfactory performance of the contract, and to be paid in one month from the time the contract is completed. In making these estimates the cubic contents of the stone will be taken, except that the rock-face projections will not be allowed for.

26. Proposals will be addressed to the New York Bridge Company, Brooklyn, N. Y., indorsed, "Proposals for Anchorage Stone."

W. A. ROEBLING,

Engineer.

SPECIFICATIONS FOR CUT FACE-STONE, BACKING AND ARCH-STONE OF LIMESTONE REQUIRED FOR THE NEW YORK ANCHORAGE, EAST RIVER BRIDGE, 1875.

1. Proposals will be received until 12 M. October 9, 1875, for the delivery of 1,000 yards Cut Backing; 899 yards Cut Face-stone; and 731 yards Arch Sheeting, all of Limestone.

2. The quantity is comprised in nine courses of masonry, as follows:

No. of Course.	Stones to be Marked.	Rise of Course.	Backing.	Facing.	Total.
29	Z	28 in.	250 yds.	216 yds.	466 yds
30	A	24 "	250 "	140 "	402 "
		12 "	—	12 "	
31	B	28 "	—	120 "	120 "
32	C	24 "	250 "	106 "	356 "
33	D	30 "	—	51 "	121 "
		20 "	—	23 "	
		32 "	—	18 "	
		Sloping, 21 to 39 in.	—	29 "	
34	E	35½ in.	— "	28 "	39 "
		Sloping. 8 to 35½ in.	— "	11 "	
35	F	26 in.	250 "	33 "	293 "
		13½ "	— "	5 "	
		12 "	— "	5 "	
36	G	26 "	— "	60 "	60 "
37	H	24 "	— "	42 "	42 "
Totals			1,000 yds.	899 yds.	1,899 yds.

RECAPITULATION.

Limestone Backing	1,000 cubic yds.
" Facing	899 "
" Arch Sheeting	731 "
Total	2,630 cubic yds.

3. Detail drawings on a scale of five feet to the inch will be furnished for every course, and templates and drawings for the archstone. A part of the stone are dimension stone, and each will be designated by a special number. Every dimension stone must be cut *full*, and *no* allowances made for joints or beds, as this has been already done.

The *bottom* bed is the one referred to in every case, and allowances for *projections* or *batter*, must be made accordingly.

4. Stones having no special number may vary in dimensions from those given on the plans, *provided* that the total lengths of wall faces are made up, and that the dimensions, as furnished, do not make it necessary to *change the bond*. With these restrictions, stretchers may range from 5 to 10 feet in length, and shall not be *less* than 2 feet 9 inches wide; and headers may range from 5 to 6 feet in length, and shall not be less than 3 feet, or more than 3½ feet in width.

5. The limestone shall be equal in quality to the Kingston limestone, or Lake Champlain bluestone. All stone with dry or flinty seams which split with frost, will be rejected.

6. The face-stone must be cut with a bold rock-face. A small portion will have plumb faces, but the greater part must be cut with a batter of one-half inch to the foot rise; this will be indicated by a note on the plan in every case. The front edges will be pitched off to a line. No draft will be required except at the projecting angle of corner stones, on which there shall be an 1½ inch draft.

7. The upper and lower beds of all stone, both facing and backing, must be rough-axed, and cut true and parallel to each other, so as to bear the straight edge all over, and allow of half-inch joints; but the cutting need not be fine. Square and parallel cutting of the beds will be insisted upon. No hollow or slack cutting or falling away towards the rear will be permitted.

No plug-holes will be allowed more than nine inches in diameter, or more than 1½ inches deep, nor within one foot of each other, or of the edge of the stone.

8. The vertical joints of the face-stone must be cut sufficiently true to make half-inch joints. They must be cut square with the face for a distance back of at least two feet. The rear part of the stone shall in no case project beyond the jointed portion; and all headers shall be jointed back *three* feet on each side. They must in all cases be perfectly plumb, and at right angles to the plane of the bed.

9. The vertical sides of the backing must be good quarry splits, with no projections greater than 4 inches.

The blocks of backing may vary in contents from 20 to 80 cubic feet; the whole lower bed, and at least three-fourths of the upper bed being equal in quality of cutting to that prescribed for the face-stone.

10. The rear faces of stretchers may be left rough as they come from the quarry. It will not be insisted upon that they shall be parallel to the front faces, although this is preferred.

Headers must run back full width for at least half their length; the tail, however, may be wider than the front, and their rear faces may be left as they come from the quarry.

11. The best bed of every stone must be the bottom bed, and the lewis-holes must be put in the top bed in every case.

12. All stones must be cut full to the rise named in the plans.

In each course there will be a tail-bond at each re-entrant angle of the masonry; and also up to *course* D, inclusive, at the inner angles of the tunnels. When these stones are headers they must be long enough to make a good bond. In all cases they must be properly jointed back, and exposed portions of their faces left rock-faced as on other face-stone.

13. Courses Z to D, inclusive, will have ten granite corners each, and course E will have six such corners.

The face-stone of course F are to be granite throughout, except over the spandrel courses of the front or curtain arches, and a portion of the rear face.

Courses G and H are to be granite-faced, except a portion of the front and rear of each.

The curtain arches are also to be of granite. The granite for these is not included in these specifications. Wherever the limestone facing comes adjacent to granite facing of any kind it must be jointed back to the full extent required by the plans.

Special elevations of the spandrel courses, and courses over the arches are given in the plans.

All *these* stones are to be plumb-faced.

The sides of course D are partly, and of course E entirely, made up of stone with the upper bed sloped $\frac{3}{8}$ inch per foot run. These stones must each be carefully cut to the dimensions given and plainly marked with letter and number.

14. There are two semi-circular arches running through the front portion of the masonry. Each of these is laid up in three separate portions, two of 27 feet each, and one of 26 feet 7 inches length; thus making six distinct arches.

The radius of the intrados is 11 feet 6 inches, and that of the extrados 14 feet 6 inches.

The outer faces of the archstone may be left as they come from the quarry. The ends and beds must be pointed off sufficiently true to allow of half-inch joints.

The intrados is to be left rock-face, but must have a two-inch chisel draft, carried entirely around the face of each stone.

The voussoirs of the arches need not be cut to the exact lengths given in the drawings, provided that the total lengths are made up in each course. But no variations of *more* than *six inches* will be allowed from the drawings; and every archstone must be *plainly* marked with its *number* and *letter*.

15. Every stone must have a lewis-hole of a clear depth of $4\frac{1}{2}$ inches, and a width in direction of thickness of lewis, of $\frac{3}{4}$ inch.

A sample *flat* lewis will be furnished to the contractor, and all holes must be cut so as to allow of its use.

No round lewis-holes will be permitted.

All lewis-holes, especially in the archstones, must be so placed that when the stones are suspended they will be in the right position for setting. All re-cutting will be charged to the contractor.

16. In case any mistakes are made in the cutting of the stone, as regards the character of the beds or joints, or in the rise, or if there are other gross violations of the provisions of these specifications, the contractor is distinctly notified that such stone will be either wholly condemned and thrown back on his hands, or else a proportionate reduction in the price will be made; the same being at the option of the Engineer.

Condemned face-stone, if received at all, will be reckoned as backing.

17. The stone are to be delivered at the wharves of the Trustees, at Red Hook.

Steam power, for unloading vessels, will be furnished by the Board of Trustees; six unloading derricks being provided at the edge of the wharf. The crews of the vessels must assist in unloading. They must bring the stone under the boom of the derrick, and must attach the hoisting block to the lewis, and furnish all labor that is required on board the vessels for unloading as rapidly as the Trustees may require.

18. The first course of stone must be delivered by November 15, or before, and the balance at the rate of one course per week, in the order of the numbers. As it is of the utmost importance that the delivery of the stone be prompt and in the order of the courses, this rate of delivery will be insisted upon; and if there are any *delays* in the delivery *from any cause whatever*, the stone will be obtained elsewhere, and the attendant expense will be charged to the contractor, together with all damages arising from delays.

19. Parties proposing must be known as men both skilled in the quarrying and cutting of stone, as well as prompt and reliable in their business transactions, and must bring satisfactory references to that effect, as well as to their financial responsibility.

20. Any question as to the intent or meaning of these specifications shall be referred to the Engineer, whose decision shall be final.

21. The Board of Trustees reserve to themselves the right to reject any or all bids offered, and to make awards of separate portions of the total quantities required, if to their interest so to do. They also reserve the right to increase the quantity of backing required beyond the amount heretofore named in this specification, provided it be required to complete this portion of the New York Anchorage.

22. Bids will be received as follows:

LIMESTONE.

For 899	cubic yards	Face-stone, delivered, per cubic yard........	$....
For 731	"	Arch Sheeting, delivered, per cubic yard.....	$....
For 1,000	"	Cut Backing, delivered, per cubic yard.......	$....

23. Monthly estimates will be made on or about the 10th day of each month, for stone delivered during the previous month, provided that no stone will be estimated for until all courses below them are completed. Payments will be made on these estimates after deducting 15 per cent., said deduction to be kept as a guarantee for the satisfactory performance of the contract, and to be paid in one month from the time the contract is completed. In making these estimates the cubic contents of the stone will be taken, except that the rock-face projections will not be allowed for. Archstone will be measured net, at three feet thickness of arch, except that projections on top, in excess of this, will be paid for as backing.

26. Proposals will be addressed to the Trustees of the New York and Brooklyn Bridge, Brooklyn, N. Y., indorsed "Proposals for Anchorage Stone."

W. A. ROEBLING,

Engineer.

SPECIFICATIONS FOR CORNERS, FACING AND ARCHSTONE, OF GRANITE, REQUIRED FOR THE NEW YORK ANCHORAGE, EAST RIVER BRIDGE, 1875.

1. Proposals will be received until 12 M., October 9th, 1875, for the delivery of 85 yards of Granite Corner-stone; 250 yards Cut Face-stone; and 31 yards Arch Face-stone, all of Granite.

2. The quantity is composed in nine courses of masonry, as follows:

No. of Course.	To be Marked.	Rise of Course.	Granite Corners.	Granite Face-stone.	Total.
29	Z	28 in.	18 yds.	....	....
30	A	24 in.	12 "	....	...
31	B	28 in.	17 "	....	....
32	C	24 in.	12 "	....	....
33	D	30 in.	10 "	....	....
		20 in.	3 "	....	....
		32 in.	4 "	....	....
34	E	35½ in.	9 "	....	....
35	F	26 in.		94 yds.	....
36	G	26 in.		81 "	....
37	H	24 in.		75 "	...
Totals			85 cub. yds.	250 cub. yds.	

RECAPITULATION.

Total Granite Corners	85 cubic yds.
" " Cornice "V" Course	94 "
" " Cornice Bevel Courses	156 "
" " Archstone	31 "
Total Granite required	336 cubic yds.

3. Detail drawings on a scale of five feet to the inch, will be furnished for every course. Special drawings will be furnished for the corner-stones and archstones, and templates for each archstone.

4. Every stone must be plainly marked on delivery, with its appropriate letter and number as given on the plans.

5. Every stone must be cut full to the dimensions given, and no allowances made for joints or beds, as this has already been done.

The bottom bed is the one the measurements refer to in every case, except where specially mentioned, and allowances must be made for batter or projections accordingly.

6. Courses Z to D have 10 granite corners in each, and course E has six. Of these all, but the two rear ones in D, and those in E, must have the beds cut *true* and *parallel*, one to the other, and must be cut full to the rise named for each. The upper bed of corners excepted above, must be sloped $\frac{3}{8}$ inch per foot run, as shown in the plans.

The beds of all the face-stone in courses F, G and H must also be parallel. The beds of all stone must bear the straight edge all over, so as to allow of half-inch joints, but the cutting need not be fine. No hollow or slack cutting will be permitted.

No plug-holes of over 9 inches in diameter, or more than $1\frac{1}{2}$ inches deep, nor within one foot of each other, or of the edge of the stone, will be permitted.

7. All vertical joints must be sufficiently true to make half-inch joints. They must be cut square with the face for the full width of the stone in the case of stretchers; and in the case of headers they must be jointed back for the full width of the adjacent stretchers.

8. For the corner-stone the vertical joints shall be at right angles to the plane of the beds. For the cornice courses F, G and H, they must be cut so as to be vertical when the bed is sloped $\frac{3}{8}$ inch per foot run, as shown in the elevations of each course.

9. The rear faces of stretchers and headers may be left rock-face. If they exceed the dimensions given in the plans, however, the excess will be paid for as backing.

10. The best bed of every stone must be the bottom bed.

11. The Granite must be uniform in color, sound and durable, free from all cracks, weak spots or sap, and without seams of any kind.

12. Each corner-stone has a four-inch projection, which is made by cutting a chamfer entirely around each face, except at the projecting corner, which is left square. The chamfer must be fine cut. The surface between the chamfers must be pointed to a uniform surface, with a projection of $\frac{1}{2}$ inch, and a $1\frac{1}{2}$ inch chisel draft cut entirely around each face. Each face has a batter of $\frac{1}{2}$ inch per foot rise, and the measurements refer to the bottom bed, the four-inch projection being in addition to the same.

13. Two Granite arches are required. These are semi-circular, with a radius of intrados of 11 feet 6 inches, and length in direction of the axis of three feet each. A special drawing and template will be furnished for each archstone.

The intrados of each stone must be smooth pointed.

The exterior face of each (except where it is hidden by the buttress masonry), is to have a $1\frac{1}{2}$ inch draft entirely around it, cut to a depth of 1 inch. The raised panels thus formed is to be smooth pointed.

The beds and rear face are to be cut true, but may be rough pointed.

The Keystones are to have a three-inch draft around each face, cut to a depth of three inches, and the panel thus made is to be smooth pointed. The exposed portions of the sides and the top of the key-stones and the intrados are also to be smooth pointed.

14. Courses F, G and H are to be cut to dimension, and the beds and joints as previously mentioned. A clean $1\frac{1}{2}$-inch draft is to be cut around every face except the > projection in course F. The space within the draft is to have half-inch projection, and be smooth pointed, and the > projection finished smooth.

Samples of the work can be seen at the anchorages.

15. The top bed of every stone must be lewised for a sample flat lewis, which will be furnished to the contractor. Every lewis-hole must have a clear depth of $4\frac{1}{2}$ inches, and a width in the direction of the thickness of the lewis, of $\frac{3}{4}$ inch.

All lewis-holes, especially in the archstones, must be so placed that when the stones are suspended they will be in the right position for setting. All re-cutting will be charged to the contractor.

16. In case any mistakes are made in the cutting of the stone, as regards the character of the beds or joints, or in the rise, or if there are other gross violations of the provisions of these specifications, the contractor is distinctly notified that such stone will be either wholly condemned and thrown back on his hands, or else a proportionate reduction in the price will be made; the same being at the option of the Engineer.

Condemned stone, if received at all, will be reckoned as backing.

17. The stone are to be delivered at the wharves of the Trustees at Red Hook.

Steam power, for unloading vessels, will be furnished by the Board of Trustees; six unloading derricks being provided at the edge of the wharf. The crews of the vessels must assist in unloading. They must bring the stone under the boom of the derrick, and must attach the hoisting-block to the lewis, and furnish all labor that is required on board the vessels for unloading as rapidly as the Trustees may require.

18. The first course of stone must be delivered by November 15th, or before, and the balance at the rate of one course per week, in the order

of the numbers. As it is of the utmost importance that the delivery of the stone be prompt, and in the order of the courses, this rate of delivery will be insisted upon; and if there are any *delays* in the delivery, *from any cause whatever*, the stone will be obtained elsewhere, and the attendant expenses will be charged to the contractor, together with all damages arising from delays.

19. Parties proposing must be known as men both skilled in the quarrying and cutting of stone, as well as prompt and reliable in their business transactions, and must bring satisfactory references to that effect, as well as to their financial responsibility.

20. Any question as to the intent or meaning of these specifications shall be referred to the Engineer, whose decision shall be final.

21. The Board of Trustees reserve to themselves the right to reject any or all bids offered, and to make awards of separate portions of the total quantities required, if to their interest so to do.

22. Bids will be received as follows:

GRANITE.

For 85 cubic yds. Granite Corners, delivered, per cubic yd....... $ ...
For 31 cubic yds. Archstone, delivered, per cubic yd............ $....
For 94 cubic yds. V course of Cornice, delivered, per cubic yd.... $....
For 156 cubic yds. Bevel courses, delivered, per cubic yd......... $....

23. Monthly estimates will be made on or about the 10th day of each month for stone delivered during the previous month, provided that no stone will be estimated for until all courses below them are completed. Payments will be made on these estimates after deducting 15 per cent., said deduction to be kept as a guarantee for the satisfactory performance of the contract, and to be paid in one month from the time the contract is completed.

In making these estimates the net cubic contents of the stone will be taken, estimated according to the exact dimensions of the plans

24. Proposals will be addressed to the Trustees of the New York and Brooklyn Bridge, Brooklyn, N. Y., indorsed "Proposals for Anchorage Stone."

W. A. ROEBLING,
Engineer.

SPECIFICATIONS FOR SADDLES AND SADDLE-PLATES FOR THE BROOKLYN AND NEW YORK TOWERS, EAST RIVER BRIDGE, 1874.

1. Proposals are invited by the undersigned up to October 1, 1874, for the delivery of eight cast-iron Saddles and eight cast-iron Saddle-plates for the Brooklyn and New York Towers of the East River Suspension Bridge.

2. Each Saddle will weigh about 25,000 pounds; four of the Saddle-plates will weigh about 22,000 pounds each, and four about 19,000 pounds each; thus making a total weight of at least 182 tons.

SADDLES.

3. The object of the Saddles is to furnish a bearing with easy vertical curves upon which the main cables and a portion of the main stays may rest in passing over the pier. In plan, they are rectangular 13 feet by 4 feet 1 inch over all; extreme height, 4 feet 3 inches, and the main portion 4 inches thick.

Over the centre of each, one of the cables passes through a groove $19\frac{1}{2}$ inches wide and $17\frac{1}{4}$ inches deep at its middle section.

On each side of the main groove are two smaller grooves, in each of which, four of the long stays are placed.

The ends and edges of the grooves are all rounded wherever there is possibility of chafing of the wires.

Seventeen openings are made underneath the grooves, to reduce weight and secure uniformity in thickness as far as possible.

4. The longitudinal edges are carried one inch below the under surface of the Saddle to make end bearings for iron rollers, upon which the whole will rest.

The inner faces of these edges must be planed true; the under surface must also be planed true, very smooth, and so as to bear a straight edge in any direction. For this purpose the contractor must make sufficient allowance in the pattern, as the dimensions given are to be those of the finished Saddle.

5. The outside of the two longitudinal edges must be true—that is, perfectly parallel and "out of wind," and free from roughness, but need not be planed.

6. The grooves must also be free from roughness, but need not be finished.

SADDLE-PLATES.

7. The Saddle-plates are to rest in seats prepared in the masonry, and form perfectly true beds, upon which the rollers supporting the Saddles may traverse.

They are to be 16 feet 2 inches long, $14\frac{3}{4}$ inches high over all, the outside ones 8 feet wide at the centre and 6 feet 3 inches at the ends; and the inside ones 6 feet 6 inches wide at the centre. The same pattern answers for the inner ones by cutting a strip from one side. The central portion is to be $4\frac{1}{2}$ inches thick, and the sides $3\frac{1}{4}$ inches thick, when finished.

There are two lugs in each side channel to which stays will be attached.

At the ends of the side channels as well as the main channel, all the edges are to be rounded off to prevent chafing.

8. The central channel is to have its surface planed perfectly true, very smooth, and so as to bear a straight edge all over. The edges which form end bearings for the rollers are also to be planed true. The vertical sides of the main ribs on the face towards the rollers must be perfectly parallel, and must be planed true.

9. Sufficient allowance must be made in the pattern for planing, in all cases.

10. The edges of the central plates, where cut off, are to have a rough cut of say $\frac{1}{8}$ inch to insure their being true and parallel, but need not be planed smooth.

GENERAL SPECIFICATIONS.

11. Complete detail drawings, which form a part of these specifications, will be furnished the contractor, and the castings are to conform to them in measurement when planed and ready for delivery.

12. All angles are to be filleted, except those abutting the ends of the rollers.

13. As soon as the castings can be removed from the sand, cleaned and dressed off, they are to receive a thorough coat of raw linseed oil. After this is hardened, a second coat of boiled linseed oil is to be applied.

After the planing is completed, the planed surfaces are to be coated with tallow and white lead.

14. The contractor is to make all patterns, do all the planing and finishing required, and deliver the finished castings either at the Tower wharves, East river, or in the yard at base of the Towers.

15. The patterns are to be the property of the Bridge Company when the work is completed.

16. The quality of the iron must be tough and strong. In order to test this, the contractor will be required to cast at least six sample bars from the same melting used in the plates. They must be 5 feet long, 1 inch square, and when placed on supports 4 feet 6 inches apart, must break with no less than a central load of 500 pounds.

Trial bars of the metal proposed to be used must also be furnished the Engineer for experiment, before the plates are cast.

17. The castings must be sound throughout, free from air bubbles, cold shuts, strains or cracks; and in order to insure freedom from strains, they must lie a sufficient time in the sand to insure slow cooling.

18. It is hereby distinctly understood that the contractor takes all risks of any cracks appearing in the castings which may arise from strains, due either to hasty cooling, shrinkage, or the shape of the patterns. If any of the castings should crack from any of these causes within one month after their acceptance, it is understood that they will be replaced by the contractor; injuries resulting from accidents while in the hands of the Bridge Company excepted.

19. Before the plates will be accepted they must be subject to the inspection of the Engineer, or his authorized assistant, at the foundry.

20. The bid for the castings will be so much per pound for the Saddles complete, and so much per pound for the Saddle-plates complete, all delivered, or a bid may be made for the whole lot at one price; and no bids will be received from such foundries as have not heretofore made castings approximating these in size and weight.

21. The Bridge Company reserves the right to reject all or any of the bids offered.

22. The *plates* will be required first, and the delivery must begin by December 10th, and must be completed before the 1st of February, 1875.

23. Monthly payments will be made about the 10th of each month for all work delivered during the previous month, reserving fifteen per cent. until the completion of the contract.

24. Bids are to be marked on the outside of the envelopes, "Proposals for Saddles and Saddle-plates," and addressed to the "New York Bridge Co., No. 21 Water street, Brooklyn, N. Y."

W. A. ROEBLING,

Chief Engineer N. Y. Bridge Co.

SPECIFICATION FOR ANCHOR PLATES, NEW YORK ANCHORAGE, EAST RIVER BRIDGE, 1875.

1. Proposals are invited by the undersigned up to April 15, 1875, for the delivery of four cast-iron *anchor plates* for the New York anchorage of the East River Suspension Bridge.

2. Each plate will weigh about 46,000 pounds, making a total weight of 92 tons for the four plates

3. The general shape of the plate is that of an oval spider, 17 feet 6 inches by 16 feet, and 2 feet 6 inches in depth. It has 16 arms, composed of heavy ribs and flanges. The centre of the plate has 18 openings for the passage of a double set of anchor chains. These openings are separated by ribs 3 inches thick and 15 inches long, and extending the full depth of the plate 2 feet 6 inches. The sides of the ribs must be true and perpendicular, and out of wind. After the plate is cast, a pattern bar must pass easily through the openings. Plans may be seen at the Engineer's office, 21 Water street, Brooklyn.

4. The upper surface of the plate must be a true surface, and out of wind throughout its entire extent.

5. The semi-circular grooves at the bottom of the ribs must be straight and true. A 5-inch pin must be fitted to them, so as to bear uniformly at every point, and lie parallel to the upper face of the plate.

6. Two of the plates will have the three arms on one side, cut two foot shorter. This must be done so as to make the plates "right and

left," in other words, cut from opposite ends. These two plates will be cast last.

7. The quality of the iron must be tough and strong. Such a mixture of iron should be used as will give great tensile strength, because the uplifting strain of the anchor chains is such as to produce a tensile strain in the upper flange of the arms, tending to break them off.

The casting must be sound throughout, free from air bubbles, cold shuts, strains or cracks.

8. In order to test the quality of the iron, the contractor will be required to cast two or more sample bars from the same melting used in the plates. They must be 5 feet long, 1 inch square, and, when placed on supports 4 feet 6 inches apart, must break with no less than 500 pounds placed in the middle.

9. Such trial bars of the metal proposed to be used by the contractor, must also be furnished to the Engineer for experiment before the plates are cast.

10. In order to insure freedom from strains, due to rapid cooling, the castings must lie in the sand for one week before uncovering.

11. Before the plates will be accepted they must be subject to the inspection of the Engineer or his authorized assistant, at the foundry.

12. The castings are to be delivered with the flat side up, on deck of a scow or vessel, at the New York tower wharf, East river.

13. It is hereby distinctly understood that the contractor takes all risks of any cracks appearing in the casting, which may arise from strains, due either to hasty cooling, shrinkage, or the shape of the pattern. If the plate should crack from any of these causes within one month after the acceptance, it is understood that the contractor will furnish a new one.

Injuries resulting from accidents while in the hands of the Bridge Company excepted.

14. The pattern will be furnished by the Bridge Company at the Brooklyn Anchorage.

15. The bid for the castings will be so much per pound, delivered.

16. The castings must be delivered by July 1st, 1875.

17. No bids will be accepted except from such foundries as have heretofore made castings approximating these in size and weight.

18. Payment will be made by the Bridge Company in one month after delivery of plates.

19. Bids to be marked "Proposals for anchor plates," on outside of envelopes, and directed to the "New York Bridge Company, 21 Water street, Brooklyn, N. Y."

W. A. ROEBLING.

Engineer New York Bridge Company.

SPECIFICATIONS FOR IRON ANCHOR BARS. NEW YORK ANCHORAGE, EAST RIVER BRIDGE, APRIL, 1875.

1. Proposals are invited up to April 19, 1875, for the delivery of about 1,027,000 pounds of iron anchor bars and about 30,000 pounds iron pins, for the New York Anchorage, East River Suspension Bridge. These bars embrace the entire chains for this Anchorage.

2. An inspection of the plan shows 4 sets of chains arranged in a curved position, and comprising 10 sets of links connected by pins in each. Each set of chains is double, consisting of 2 tiers of links, one above the other, and secured at the bottom to one anchor plate.

3. The total contract comprises:

Sets.		Weighing.
1, 2, 3.	200 bars, with a section in the body of the bar, 7 in. by 3 in. 16 " " " " 7 " 1½	231,000 lbs.
4, 5, 6.	216 bars, with a section in the body of the bar, 8 in. by 3 in. 24 " " " " 8 " 1½	294,000 lbs.
7, 8, 9 & 10.	216 bars, with a section in the body of the bar, 9 in. by 3 in. 184 " " " " 9 " 1½	500,000 lbs.
Total	856 bars	1,025,000 lbs.
	4 bars, 8 inches by 1 inch, about	2,000 lbs.
	80 pins, about	30,000 lbs.

4. The different sets of links and pins will consist of the following sizes and lengths:

Position of Links. — Chains.	No. of Bars.	Sizes of Bars. — inches.	Length of Bars. C. to C. of eyes.	Sizes of holes in heads.	No. of Pins.	Sizes of Pins.	Lengths of Pins.
No. 1 Upper.	28 8	7 x 3 7 x 1½	13 ft. 9 in. " "	for 5 in. pins. " "	4 pins.	5 in. diam.	58 in.
No. 1 Lower.	36	7 x 3	" "	" "	"	" "	"
No. 2. Upper.	32	7 x 3	" "	" "	"	" "	58½ "
No. 2. Lower.	32 8	7 x 3 7 x 1½	" " " "	" " " "	"	" "	63¼ "
No. 3. Upper.	36	7 x 3	13 ft. 3½ in.	for 5 in. pins	4 pins. "	5 in. diam. " "	61½ " 64¾ "
No. 3. Lower.	36	7 x 3	12 ft. 10 in.	" "	" "	" " " "	63¼ " 66¼ "
No. 4. Upper.	32 8	8 x 3 8 x 1½	13 ft. 3½ in.	One 5 in. and one 6 in. pin.	"	6 in. diam.	64¾ "
No. 4. Lower.	40	8 x 3	12 ft. 10 in.	" "	"	" "	69½ "
No. 5. Upper.	36	8 x 3	13 ft. 3½ in.	for 6 in. pins.	"	" "	64¾ "
No. 5. Lower.	36 8	8 x 3 8 x 1½	12 ft. 10 in. 12 ft. 10 in.	" " " "	"	" "	69½ "
No. 6 Upper.	32 8	8 x 3 8 x 1½	13 ft. 3½ in.	One 6 in. and one 6½ in. pin.	"	6½ in. diam.	64¾ "
No. 6. Lower.	40 4	8 x 3 8 x 1	12 ft. 10 in.	" "	"	" "	75 "
No. 7. Upper.	36	9 x 3	13 ft. 3½ in.	One 6½ in. and one 7 in. pin.	"	7 in. diam.	65 "
No. 7. Lower.	36 8	9 x 3 9 x 1½	12 ft. 10 in. 12 ft. 10 in.	" " " "	"	" "	69½ "
No. 8. Upper.	32 8	9 x 3 9 x 1½	See paragraph No. 5 as to lgth	for 7 in. pin. " "	"	" "	68 "
No. 8. Lower.	40	9 x 3	12 ft. 10 in.	" "	"	" "	69½ "
No. 9. Upper.	36 8	9 x 3 9 x 1½	13 ft. 3½ in. " "	" " " "	"	" "	68 "
No. 9. Lower.	36 8	9 x 3 9 x 1½	" " " "	" " " "	"	" "	69½ "
No. 10.	152	9 x 1½	17 ft. 5 in.	" "			

5. The length of the link No. 8, in the upper chain, cannot be determined until the lower bars of the same link are set in place. They will

probably be a little longer than 13 feet 3½ inches, but will not exceed 13 feet 6 inches, so that the iron can be rolled of the latter length, in advance, if desired.

6. Each bar will be forged with a head at each end, and inasmuch as the sizes and shapes of heads vary according to the mode of upsetting employed, such shape will be determined on by the Engineer after the contract is let; provided, however, that the dimensions shall be such as, with the form employed, will, in the judgment of the Engineer, give a strength of head equal to that of the body of the bar.

7. The heads must, in all cases, be upset on the solid bar, and not welded on. All heads of one size must be of a uniform and regular outline. They must be forged smooth and flat. The bar, as well as the head, *must* be *out* of *wind*, and not *bent* to one side or *twisted*. The thickness of the head must not exceed that of the bar by more than ⅛ of an inch, and in no case must it be less than the bar in thickness. The heads, on set No. 1 must be as nearly as possible of the exact thickness, as it will be impossible otherwise to pass them through the anchor plates.

Particular attention is called to this section, for the reason that in every case before the insertion of any set of bars (after the first) the preceding set is rigidly fixed in the masonry, and the intent is to leave the smallest possible space between the sides of the heads.

8. Each chain has a width of about 6 feet, and each pin passes through from 17 to 31 bars. It is, therefore, essential that the bars be drilled exactly at right angles to their length, and with absolute exactness as regards the distance between the holes, so that the pins may pass at right angles through the sets when in position.

An important point to be observed here is, that the heads shall not be sprung when clamped in the drill press, otherwise the holes will not be at right angles to the bars, and the pins will bind in them when the bars are placed in position.

9. The holes must all be drilled with a play of 1-32 of an inch; that is, with a diameter 1-32 of an inch in *excess* of that given for the pin.

10. The Engineer will make the following test, as to length, of each set of bars: Nine bars of the set, selected at random, shall be laid over each other, and separated by three-inch blocks, and the proper pins passed simultaneously through the two ends without difficulty.

All the bars shall be at the same temperature while making the test.

The contractor shall furnish the labor and facilities for making the tests, and shall retain at least two pins of each diameter, until the tests have been made.

PINS.

11. The pins will be turned off so as to gauge throughout their length to the *exact* diameter mentioned, the allowance for driving having been made in the pin-holes.

To facilitate driving, the pins must have the angles at the ends slightly rounded.

12. The pins must be of hammered iron, and must be equal in quality to that in the bars.

13. The Bridge Company reserve the right to reject any or all bids, or to award portions of the total quantity to different contractors. In case this be done, the lots will be as follows: sets 1, 2 and 3 in the first; sets 4, 5, 6 in the second. and the remainder in the third lot.

The contractor for any lot succeeding the first, will be furnished with a template of the pins in the upper end of the set preceding, so as to insure the certainty that these pins will fit the holes he has to drill.

QUALITY OF IRON AND TESTING.

14. The iron shall be that known as "double refined." It shall be perfectly sound, and free from all blemish, either in the original bars, or after the heads are made, such as burning, unsound welding, or cracks of any kind.

Its breaking strength shall be not less than 50,000 pounds per square inch.

For the purpose of testing this, the Engineer shall have the right to select at random one or more bars from each lot of those provided for each set of links. From the bar so selected, the contractor shall cut out three test pieces, one near the centre, and one near each end.

These pieces shall, without working of any kind, be turned down to fit some standard testing machine, and so as to give a uniform section of one inch diameter for six inches of length.

The average breaking strength of these specimens may be considered the strength of the bar.

They shall stretch in breaking at least ten per cent. of their length, and shall bear a strain of 20,000 pounds per square inch, without permanent set.

If the test on the first bar be satisfactory, no other bar of that lot will probably be tested (provided the iron is all from the same maker, and the Engineer is satisfied with the appearance of the remainder of the bars), and the contractor may proceed with the manufacture of the links.

If the first test be unsatisfactory, more tests will be made, and the Engineer shall have the right to reject all the bars of any lot, should he have reason, after a sufficient number of tests, to consider the iron unreliable. He may also reject the links after manufacture, if the eyes are not properly made, or the iron has been injured in making them.

The contractor shall furnish the extra bars for these tests without charge.

It will be seen this will require at least ten additional bars in all to be furnished.

Bars injured in rolling or in making the heads may be used for making tests from, so that the expense for extra bars will be small.

It is understood that the object of these tests is to insure a sound, tough iron, in the finished work. Testing enough to insure this will be insisted upon, and no more.

16. In addition to this test, the 1½ inch bars shall each be tested by the contractor to a strain of 20,000 pounds per square inch of section. Such bars as show a permanent set under this strain shall be rejected.

17. All tests shall be made at the expense of the contractor, and under the direction of the Engineer of the Bridge Company, or his authorized assistant, the contractor to supply the testing machine and the requisite labor.

18. All bars are to be delivered on board of a vessel or lighter, at the New York Tower wharf, and are to be unloaded with the assistance of the crew, the Bridge Company furnishing the power and derricks.

19. The links in set No. 1 must be furnished by July 1st; those in set No. 2 by July 15th, and the remainder at the rate of one set per month; the delivery being completed by April 1st, 1876.

20. The Bridge Company will make payments in current funds on the 10th day of every month, for all pins and bars delivered during the previous month, 10 per cent. of the contract price being retained until the completion of the contract. When the contract is completed, and all the bars are delivered, a final payment, including the back percentage, will be made on the 10th of the ensuing month.

21. Proposals will be addressed to the New York Bridge Company, No. 21 Water street, Brooklyn, N. Y., marked "Proposals for Anchor Bars and Pins."

W. A. ROEBLING,
Chief Engineer New York Bridge Co.

SPECIFICATIONS FOR WIRE ROPES FOR THE EAST RIVER BRIDGE.

1. Proposals will be received until the first day of February, 1876, for the manufacture and delivery of the following Steel and Iron Wire Ropes, required for the erection of the temporary foot-bridge, cradle cables and other appliances necessary for the construction of the main cables of the East River Suspension Bridge.

The lengths and sizes of the rope are as follows:

I.—STEEL ROPES.

2. (*a.*) Two (2) galvanized steel foot-bridge ropes, each rope to weigh 12 lbs. per foot and to be scant 2⅝ inches in diameter, with a breaking strength of not less than 240 net tons.

The lengths are uneven, as follows:

One rope to be.................................3,625 feet long.
The second rope to be.........................3,688 feet long.

(*b.*) Three (3) galvanized steel cradle ropes, each weighing 9lbs. per foot, and to be full 2¼ inches in diameter. Each of these ropes has a length of 3,625 feet, and a breaking strength of not less than 18 tons.

(*c.*) One (1) galvanized steel carrier rope, weighing 3 lbs. per foot, and being about $1\frac{3}{8}$ inches in diameter, having a length of 3,710 feet, and a breaking strength of not less than 60 tons.

(*d.*) Four (4) galvanized steel working ropes (for pulling over wires), weighing $\frac{7}{8}$ lb. per foot, and being $\frac{3}{4}$ inch in diameter, each rope having a length of 3,800 feet, and a breaking strength of not less than than 18 tons.

(*e.*) Four (4) galvanized steel pendulum ropes (for separating strands), weighing $\frac{3}{4}$ lb. per foot, and having a diameter of 11-16 of an inch. Each rope has a wire core, and a length of 3,700 feet.

II.—IRON ROPES.

(*f.*) Two (2) galvanized iron hand-rail ropes, composed of seven wires to the strand, No. 17 gauge, with a tarred Manila core and ordinary lay, not too long. Length of each rope 3.500 feet.

(*g.*) Under-floor foot-bridge guys. They have an aggregate length of 10,868 feet, and a thickness of 11-16 of an inch. The rope to be composed of six strands around a hemp centre, and to weigh $\frac{3}{4}$ lb. to the foot. Each strand must have seven wires, No. 15 gauge, galvanized, and made of best (*b. b.*) charcoal iron.

(*h.*) Suspender cords, weighing 9 feet to the pound, and consisting of one strand of seven No. 14 galvanized charcoal wires. An aggregate length of 8,000 feet will be wanted.

CONSTRUCTION OF ROPES.

3. (*a.*) The foot-bridge ropes will be composed of six strands, laid around a central core, all of equal size. The outside strands will contain 19 wires each, but the core, in place of being a strand, will be a regular laid rope, composed of six strands and a core, each containing seven wires. The wires of this rope core must be of the proper size, so as to give it the same diameter as the strands. The lay of the rope core must be the same as the lay of the outside strands, which may be either right lay or left lay. The size of the various wires must be so proportioned as to give a total weight of 12 lbs. per foot. No projecting wires can be allowed in the strands. The strands must be round. The lay of these ropes will be that known as long lay; that of the strands in the rope being not less than one turn in $17\frac{1}{2}$ inches, nor more than one turn in $18\frac{1}{2}$ inches.

(*b.*) The construction of the cradle ropes will be similar, viz.: Six outer strands around a centre. Each outer strand will contain 19 wires, and the central strand will be the same as the outer ones, differing in that respect from the foot-bridge ropes. The size of wires must be proportioned, to give a weight of 9 lbs. per foot to the rope. The lay of these ropes will also be long lay; not less than one turn in $14\frac{1}{2}$ inches, nor more than one turn in $15\frac{1}{2}$ inches.

(*c.*) The carrier rope will be composed of six strands around a wire centre, each strand containing 7 wires, No. 9 gauge. The lay of the rope will be moderately long, about one turn in 9 inches.

(*d.*) Each working rope will be composed of six strands of seven No. 14 wires each, laid around a central core of best tarred hemp. As these ropes are intended for running ropes, they must have a moderately short lay of about one turn in 6¼ inches; and, as these ropes are to be spliced into endless ropes, they must all have the same lay.

(*e.*) The pendulum ropes will be composed of seven No. 15 wires in each strand, with a wire centre, and made in the same way as the carrier rope. The lay will be moderately long, about one turn in 6¼ inches.

(*f.*) The construction of the iron ropes is sufficiently described in paragraph 2, under the headings *f*, *g* and *h*.

STRENGTH AND QUALITY OF STEEL WIRE TO BE USED.

4. All the steel ropes are to be made of the best quality of hardened and tempered galvanized "crucible cast-steel" wire. No "Bessemer" wire, or "Siemens-Martin" steel wire, or "Open Hearth" steel wire can be accepted. The strength required is at the rate of 160,000 lbs. per square inch of section. This rate is not excessive, and can easily be obtained by manufacturers of such wire. It requires, for instance, that No. 7 wire, weighing 12 feet to the pound, shall have a breaking strength of $\frac{160000}{3 \cdot 36 \times 12}=3,966$ lbs.. No. 8 wire, weighing 15 feet to the pound, shall have a breaking strength of not less than $\frac{160000}{3 \cdot 36 \times 15}=3,175$ lbs. No. 9 wire, weighing 17 feet to the pound, shall have a breaking strength of not less than $\frac{160000}{3 \cdot 36 \times 17}=2,384$ lbs., etc., etc.

Specimen, with this breaking strength, must stretch at least 2 per cent., and must have a limit of elasticity not less than ⅜ of the breaking strength—that is to say, a sample of wire stretched up to ⅜ of its breaking strength must recover itself without any appreciable permanent set. When the manufacturer has prepared a sufficient quantity of wire for these ropes, he must notify the Engineer or his authorized assistant, who will test a sufficient quantity of the wire to see if it comes up to the above standard. He will continue these tests from time to time, in order to insure a uniformity throughout the manufacture. All these tests will be made after the wire is galvanized, and not before. The manufacturer must furnish the testing machine for this purpose. The necessities of the case require that all our ropes must be suspended with a very small deflection. The strain is consequently very great, arising as much from their own weight as from the load placed upon them. An increase in the size of the ropes would, therefore, increase the margin of safety but little, and we are compelled to rely entirely upon the superior quality of the material used in order to be safe.

The rates of strength in the Nos. 7, 8 and 9 wires are given as examples. The precise weight of wire must be determined by the manufacturer, so as to produce the weight per foot of rope specified. Where nothing is said to the contrary, the Birmingham wire gauge is understood to be standard.

5. All the steel wire used in these ropes must be properly soldered with brass solder: no other kind of joint can be allowed. This joint must be galvanized, so that there is no interruption in the continuity of the zinc covering. In no case will it be permitted to stick in the ends of the wire loose in place of the proper joint. Inasmuch as the size of wire used is very coarse, the rings will be small and joints very plenty. It is, therefore, required that rings weighing not less then 50lbs. shall be used.

6. In order to diminish the stretch of these ropes as much as possible, it is desirable they should be laid up under great strain, at least one-tenth of the breaking strain. This strain must be uniform on all the strands.

7. All these ropes, as well as strands, must be made in one piece, of the whole length required, and in no case can the splicing of a whole strand be permitted.

GALVANIZING.

8. All the wires used in these ropes must be completely and thoroughly galvanized. This is a very important matter, as the durability of the ropes depends entirely upon it. The ropes will be subjected to the direct influence of salt air, not only during their temporary use, but also when used as stays in the permanent work. Some of the smaller ropes will even be dragged through the salt water. The galvanizing must therefore not only be very perfect on the wire, but great care must be taken not to scrape any off in manufacturing the ropes.

The Inspector appointed for the Trustees will inspect the wire before it is laid in the rope, and reject all rings which show uncovered spots, scales, cracks after bending, or other imperfections in the coating of zinc.

Another important point—for the consideration of the manufacturer alone—is to have the steel wire galvanized in such a manner as not to diminish the temper, hardness or breaking strength thereof. The Trustees of the Bridge are fully protected in this respect, because the wire will be tested only after it is galvanized.

9. Each of the four working ropes, as described in paragraphs 2 and 3, under heading (*d*), is to be marked by the manufacturer with a prominent mark, such as paint, or a wire wrapping, to designate the point at which these ropes will rest on the top of the New York Tower. This point will come at a distance of 1,070 feet from the outer end of the rope as it lies coiled on the reel, or its equivalent distance of 2,730 feet from the inner end of the rope.

10. The ropes will be wanted in the following order: First, the four working ropes (*d*); next, the carrier rope (*c*); next, one cradle rope (*b*); next, two foot-bridge ropes (*a*); next, the two cradle ropes (*b*); next, the under-floor guys and suspenders (*g*) and (*h*); next, the hand-rail ropes (*f*); and, lastly, the four pendulum ropes (*e*). All these ropes must be delivered in three months after the letting of this contract.

11. All the ropes must be mounted or coiled on strong vertical reels, with extra thick wooden sides, provided with an opening for a horizontal spindle on which to revolve them. The side of the reel must be of extra width, to admit of the application of breaks in paying off. Reels must be made of extra strength and size, so as not to be smashed by the great weight of the ropes in handling and moving them. The reels will be paid for extra. In no case can these ropes be received in a loose coil, because they have to be transported through crowded streets of a city. A coil is, moreover, unsuited in other respects for handling the rope.

12. These ropes may be delivered either directly at the New York Anchorage, or on board of a boat, lighter or scow, at Pier 29, East river, where the Trustees of the Bridge will do the unloading. If delivered on a scow, they must be loaded on deck, resting on heavy timbers. The deck of the scow must be strong enough to stand the moving of the heavy load. It also must be high enough to be even with the dock at mean high water. The four working ropes must, in any case, be delivered at Pier 29.

13. Payment will be made in current funds, on the 10th of every month, for all ropes delivered and accepted during the preceding month. Bids to be made at so much a lb., in currency, for each of the different sizes.

Proposals must be addressed to the "Board of Trustees of the New York and Brooklyn Bridge," 21 Water street, Brooklyn.

Bids will only be entertained from parties of reputation and experience in the manufacture of wire rope, and who have ample facilities for executing this contract in time.

W. A. ROEBLING,
Engineer New York and Brooklyn Bridge.

SPECIFICATIONS FOR STEEL CABLE WIRE, FOR THE EAST RIVER SUSPENSION BRIDGE.—1876.*

1. Sealed proposals will be received by the Trustees of the New York and Brooklyn Bridge, up to the 1st day of December, 1876, for the manufacture and delivery in Brooklyn, N. Y., of 3,400 net tons or 6,800,000 lbs. of Steel Cable Wire, for the East River Suspension Bridge.

2. For the information of parties living abroad it may be stated, that the East River Bridge will connect the two cities of New York and

*These specifications are inserted here exactly as they were originally issued, but the following has to be noted, namely:

The figure of 29,000,000 was used as the modulus in the calculations for the tests in paragraphs 10 and 5.

In the foot note the words "one-third of its strength is taken up in supporting its own weight," should have read "one seventeenth (1-17th) of its strength, etc.'

Brooklyn, which are separated from each other by an arm of the sea, called the East river. That the Bridge has one main span of 1,600 ft., and two side spans of 930 ft. each, besides approaches at each end, making a total length of more than one mile. The main floor is suspended by 4 cables, each 15 in. in diameter, each cable composed of 6,300 parallel laid wires, which are laid up in place, and it is for the manufacture of these cables that the steel wire, called for in these specifications, is required.

3. The general character of the wire is as follows: it must be made of steel; it must be hardened and tempered; and, lastly, it must all be galvanized.

4. The size of the wire shall be No. 8 full, Birmingham Gauge. A length of 14 ft. must weigh exactly 1 lb. before it is galvanized, but the weight of the galvanized wire is taken in making up the 3,400 tons.

5. Each wire must have a breaking strength of no less than 3,400 lbs. This corresponds in wire weighing 14 ft. to the lb., to a rate of 160,000 lbs. per sq. in. of solid section. The elastic limit must be no less than $\frac{47}{100}$ of the breaking strength, or 1,600 lbs. Within this limit of elasticity, it must stretch at a uniform rate corresponding to a modulus of elasticity of not less than 27,000,000 nor exceeding 29,-000,000. The quality of the wire, in regard to its stretching, is further alluded to under the head of "Tests."

QUALITY OF WIRE.*

6. The rods of which the wire is made, must be of a superior quality of steel, suitable for wire purposes. It is not implied that the highest priced steel shall be used, such as is required for fine cutlery, springs, or the like, but it is only a superior steel rod, which will make a wire that comes up to the standard here laid down.

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* NOTE.—It may not be amiss here to present a few of the reasons which led to the selection of the size and quality of steel wire adopted in these specifications. In all previous bridge cables, charcoal iron wire of either No. 10 or No. 9 gauge was used. In iron wire it is well known that a remarkable increase in strength is developed by the process of cold drawing. Thus a bar 1 inch square, having a strength of 40,000 or 50,000 lbs. to the square inch, will show a rate of from 90,000 to 100,000 lbs. per square inch of section, when drawn down to No. 9 or No. 10 size. In steel, this is also true to a moderate extent, while the process of tempering and hardening still farther increases the strength. The use of this size has three advantages. The first is, that fewer wires are required to make up the cable, thus reducing labor. The second is, that its greater weight offers greater resistance to the wind—a most important consideration when laying a cable in a locality as exposed as the present one. The third, that it offers less comparative surface to rust. The use of a size much coarser than No. 8 is, however, barred by the extreme stiffness of the material, making it very troublesome to handle.

In the question of strength, as regards the choice between using iron and the various grades of steel for cables, we find that the great length of the main span

In case the billets or rods are not made by the contractor for the wire, it is to be understood that the inspector, on the part of the Trustees, is to have ample facility to satisfy himself, by ocular proof, that they are actually made out of suitable steel, and from uniform stock.

HARDENING AND TEMPERING.

7. The standard called for in these specifications, demands that this steel wire shall be of a uniform medium quality; that is, it must be neither too hard or high in its character, nor too soft or low in its temper. In order to insure this uniform quality, it is necessary that all the cable wire shall undergo the operation of hardening and tempering. The particular manner in which this operation shall be performed is not prescribed here, but is left free to the manufacturer. There are at least four methods known to the Engineer, all of which can produce good results, if properly adapted to this size of wire. Some of these processes are controlled by patents; others are of a secret nature. Whatever the process pursued by the manufacturer may be, the Engineer, or his inspector, must have satisfactory evidence that every ring of wire has undergone this operation. At the same time, the manufacturer must not lose sight of the fact that the wire is to be galvanized, after being hardened and tempered. It is not intended, however, that this paragraph shall be an absolute bar to any other mode or process of manufacture of the steel and steel wire, provided the requirements in the foregoing paragraphs are strictly fulfilled; it being believed, at the same time, that only the operation of hardening and tempering will produce such wire.

GALVANIZING.

8. The cables of the East River Bridge are suspended directly over a salt water stream, and are, in addition, exposed to the salt air of the neighboring sea-shore. Experience has shown that the ordinary means of protection, such as paint, oil or varnish, which would be ample in

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at once excludes the use of iron or the lower grades of steel. Even with the quality called for in these specifications, one-third of the strength is taken up in supporting its own weight; hence the use of iron wire bearing only 90,000 lbs. per square inch, or of the lower grades of steel, is not admissible, because it would necessitate a cable of such weight and size that it would become unmanageable, and involve the greatest difficulties in making it. I, at least, would not be willing to undertake it. The rate of strength decided upon, namely, 160,000 lbs. to the square inch, represents a fair mean of all the objects that it is desirable to attain. It is true that steel wire of a very much higher rate of strength can be made. Its use would produce a cable much smaller than 15 inches in diameter. Now it is just as undesirable to have too small a cable as too large a one. A certain bulk of cable is absolutely necessary in order to give a mass, and the inertia to resist dangerous oscillations in the cable itself. I would furthermore state, that the dimensions of the anchor chains, the sizes of the saddles and plates, the weight of the anchorages and the shapes of the towers, have all been proportioned for a cable 15 inches in diameter, and made of steel wire of the strength above given. W. A. R.

the interior, are totally inadequate to prevent rusting, in localities so near the coast. The only certain safeguard is a coating of zinc, which acts by its absolute air-tightness, as well as by its galvanic action, and is not easily abraded.

The galvanizing must be done throughout, in a thorough and perfect manner; each ring will be inspected in this regard by the inspector, when he tests the wire. All rings will be rejected which show spots imperfectly covered, or are full of rough lumps, showing a defective stripping. The galvanizing must be of uniform thickness, and must not scale off, or show any cracks, when the wire is bent.

The attention of the manufacturer is particularly called to the point that he must galvanize at such a temperature and in such a manner as not to destroy the temper of the wire. The manufacturer must run the whole risk in this respect, because the wire is inspected and tested after it has been galvanized. Samples which have been received and tested, show that it is not difficult to reconcile these two operations, and that when proper caution is exercised, and the parties possess sufficient experience, the wire can be properly galvanized without impairing the temper.

STRAIGHT WIRE.

9. All the wire called for in these specifications must be "straight" wire; that is to say, when a ring is unrolled upon the floor the wire behind must lie perfectly straight and neutral, without any tendency to spring back in the coiled form, as is usually the case. This straight condition must not be produced by the use of straightening machines of any kind, as they only injure the strength and elasticity of the wire. As the cables can only be laid up with straight wires, this necessity is obvious.

To produce straight wire it is necessary to lead the wire from a point within the galvanizing trough in a straight line, under considerable tension to the guide sheave or winding drum, and to locate the sheave or drum at such a distance as to permit the wire to be cooled and set before it is coiled thereon. And also to make the sheave or drum of such size as will not cause a permanent bending of the cooled wire. Any method of cooling the wire more rapidly will permit of a less distance between the trough and drum. As the process above described has been patented, the Trustees of the bridge have arranged with the patentee in reference to all the wire called for in these specifications, so that parties furnishing said wire will not be required to pay a royalty thereon.

MODE OF TESTING.

10. Owing to the uncertain character of steel, and the percentage of rejection that usually attends the finished product, notwithstanding all the care and the amount of selection it may have undergone in the

various stages of its manufacture, the Engineer considers it absolutely necessary that every ring should undergo a test when finished.

There will be four kinds of tests.

Firstly.—One ring in every forty (40) will be tested, as follows: a piece of wire, sixty (60) feet long, will be cut off from either end of the ring, and it will be then placed in a vertical testing machine. An initial strain of 400 lbs. is now applied, which should take out every crook and bend. A vernier gauge, capable of being read to $\frac{1}{10,000}$ of one foot, is so attached as to indicate the stretch of 50 feet of the wire. Successive increments of 400 lbs. strain are then applied, and the vernier read each time, until a strain of 1,600 lbs. is reached.

The conditions now are as follows: that the amount of stretch for each of these increments shall be the same, and that the total stretch between the initial and terminal strains shall not be less than $\frac{97}{1,000}$ of one foot, equal to $\frac{194}{100,000}$ of the 50 feet. And furthermore, on reducing the strain to 1,200 pounds there shall be a permanent elongation not exceeding $\frac{1}{100,000}$ of its length.

The same wire will then be subjected to a breaking strain, and the total amount of stretch noted. The minimum strength required is 3,400 lbs., equal to an ultimate strength of 160,000 lbs. per square inch. The minimum stretch, when broken, shall have been 2 per cent. in 50 feet, and the diameter of the wire at the point of fracture shall not exceed $\frac{15}{100}$ of one inch.

Secondly.—One ring out of every five shall be tested by having a piece 6 feet long cut off, and placed in a testing machine with vernier guage, so attached and graduated as to read the stretch of 5 feet of length to $\frac{1}{10,000}$ of one foot. When strains shall be applied in the foregoing order, and the vernier read at each point respectively, if the results correspond with the requirements for the 50 feet lengths, as regard modulus and limit of elasticity and ultimate strength, and the stretch of 5 feet of length exceed 3½ per cent. of its length, the ring will be accepted; otherwise it will be rejected.

Thirdly.—Every ring will be tested by having a piece 16 inches long cut from either end, and placed in a testing machine, having a vernier guage so arranged as to include one foot in length of the wire, and shall be graduated as finely as practicable. Each piece will be subjected to the same strains mentioned for the 5 feet lengths, and the results must correspond with the requirements before mentioned, excepting that of the ultimate stretch.

These shorter pieces are used to expedite the testing, and to economize wire; but the requirements mentioned in connection with the 50 feet tests will be insisted on, and any doubt as to results with the shorter pieces may be solved by testing a piece 50 feet long. And in case one ring in forty (40) should not be a sufficient test of the quality, then the inspector can select, at closer intervals, rings for 50 feet tests. If want of uniformity is suspected, a piece of 5 feet in length may be taken from the other end of the ring.

Fourthly.—Every ring will be subjected to a bending test by cutting off from each ring a piece of wire one foot long, and coiling it closely and continuously around a rod one-half inch in diameter, when, if it breaks, it will be rejected.

GENERAL REMARKS ON TESTING.

At the first glance these tests may seem rather onerous and exacting in their requirements, but they will not appear so to a manufacturer who has been in the habit of having his work tested, and is desirous of not only maintaining, but adding to an established reputation. The spirit of these tests does not consist so much in the rejection of a random ring here and there, as it does in impressing on the operatives, and all concerned, the assurance that no bad work can possibly pass the inspection. It is only when this has become a certainty that we can rely upon a steady and uniform character in the quality of the wire.

Nothing is more common, for instance, than to lose the whole of the day's work by reason of a wrong temperature in the galvanizing bath, or to spoil tons upon tons, by faulty tempering, all of which would be pushed for acceptance if there were no daily inspections going on. This is usually the case towards the end of a contract when the final deliveries are wanted in a hurry. Finally, it may be said that in these tests no unattainable standard has been set up, but the requirements are such as can be filled with ease and certainty by many manufacturers.

INSPECTORS AND MACHINES.

12. The inspection will be performed by the authorized assistants of the Engineer, or by specially appointed inspectors. They are paid by the Trustees. The testing machines, however, as well as all manual labor required in handling the wire, preparing the specimens. and the actual work of testing, must be furnished by the manufacturer. The testing machines will probably not be more than three in number, and this will be comparatively a small expense, as their capacity need not exceed two gross tons. After the system of inspection has once been thoroughly organized it will be found that the expense connected with it forms an exceedingly small percentage of the total cost of the wire. Proper room and facilities must be furnished for this work.

In case of any dispute arising between the inspector and the manufacturer, the Engineer is to be the sole arbiter.

SIZE OF RINGS.

13. Long rings are indispensable The weight must average 60 lbs. None weighing less than 50 lbs. will be received, and they may be as much heavier as can be made, provided the ends are of uniform diame-

ter. With the recent improvements in rolling machinery, long rings have become the rule instead of the exception, as was formerly the case. By having long rings the time and labor of splicing the wire is reduced proportionably. The splice being the weakest spot we increase the average strength by having long rings, and by reducing their number. The wire is, besides, of so coarse a size, that even a 60 lb. ring will not much more than reach half-way across the main span. Hence, at the best, the relative number of splices will be far greater than in any previous cable. The rings must be of such a diameter as not to give the wire a permanent bend. The inspectors will also pay particular attention that both ends of these long rings have the same uniform gauge and thickness—as wire of uneven weight cannot be properly regulated in making the strands. This examination will be made before the wire is galvanized.

Only one nipper mark can be permitted on the end of a ring, and that at a distance not exceeding 5 in. from the end.

When the end of the wire is pulled through the draw plate for the purpose of fastening it to the block, it must be done at one operation, and not by successive applications of the nippers, as is usually done.

The dents caused by the nipper jaws injure steel wire very materially, and hence *not more than one is allowed.*

GENERAL REMARKS AND TIME OF DELIVERY.

14. It is required that the manufacturer will at once, upon the giving out of this contract, prepare to make and deliver about 50 tons of this wire. This is necessary, in order that the contractor can make the necessary preparations in the various processes of the manufacture, so as to be able to turn out the regular quantities in the time specified. In these preliminary 50 tons ample time is given to overcome all defects which may exist in the beginning, and also to come to a perfect understanding with the inspectors as regards any doubtful questions which may arise in regard to the modes of testing or the standards required.

The regular deliveries of wire will commence February 1st, 1877. The amount of these monthly deliveries must be no less than 150 tons, and in case it should be found that the cable-making proceeds faster than at present anticipated, the manufacturer must increase this amount to 200 tons, upon being duly notified by the Engineer, at least two months in advance.

15. Inasmuch as the precise quantity of wire in these cables cannot be ascertained until some of the strands are actually made, and all the wire composing a strand has been weighed, the Engineer reserves the right to increase or diminish the quantity of wire called for in this contract by the amount of 200 tons, the same to be furnished at the regular contract price, provided he gives notice to that effect three months before the completion of the contract.

16. All parties who expect to bid on this wire are requested to send samples in accordance with these specifications, the samples to weigh no

ess than 100 lbs., and to contain two rings. Foreign parties may con-sign them to E. L. Alexander, 117 Liberty street, New York, marked Bridge wire.

17. The wire intended for shipment should be properly packed, and so wrapped as to avoid injury to the galvanizing.

MANNER OF BID.

18. Bids will be received at so much per lb., GOLD, for the whole amount delivered at the Brooklyn Tower. It is deemed best to place the bids on a gold basis, in order to eliminate the question of the probable changes in the value of the currency for the period of time over which this contract will extend. It would be impossible to foresee these changes accurately, and the margin that the contractor would be forced to allow himself would, of necessity, be against the interests of the Bridge. The duties on both the steel rod and on the finished wire are payable in gold. The duties on this kind of wire are at present 2½ cents per lb., and 20 per cent. ad valorem. The cost of lighterage from the foreign steamship wharves on the North River, to the wharf at the Brooklyn Tower, is about 65 cents per ton in currency. Ocean freights of course differ, according to shipping port.

No bid will be received which does not include the duties.

BONDS.

19. In order to insure the complete and satisfactory performance of the requirements laid down in these specifications, the successful bidder shall give good and sufficient bonds to the amount of $50,000—gold. This will take the place of the back percentage which has usually been retained in other contracts.

PAYMENT.

20. The Trustees will pay on the 10th of every month, in full, in gold, for all the wire delivered during the previous month.

21. It is furthermore to be understood by the successful bidder, that if at any time during the performance of his contract he shall fail to comply with the terms of these specifications and produce a wire which does not come up to the test required, and has to be constantly rejected by the inspectors, or if he is manifestly unable to produce the necessary quantity in the required time, the Engineer of the Trustees shall duly and officially notify him, in writing, of this neglect and failure on his part, and if, notwithstanding this notice, the required improvement is not made, then the Trustees may declare his contract null and void, and shall have the right to contract with other parties at either the same price or some other price, and if loss should occur to the Trustees by this transaction, that they then have the right to take the whole or part of the aforementioned bonds of $50,000, to cover themselves from such loss.

22. On the other hand, if from some unforeseen circumstance, which at

present the Trustees have no knowledge of, they should be compelled to suspend operations on the work, they reserve the right to notify the contractor to suspend the delivery of the wire, either for a fixed or an indefinite period, provided they serve him with a notice to that effect, at least three months before such suspension; and the fact of having given such a notice is to be a bar against any claim for damages arising from the suspension of this contract.

23. The Trustees reserve the right to reject any or all the bids that may be offered, or to divide the contract into not more than four portions, in case it should prove to their interest to do so.

24. Bids must be addressed to the Trustees of the New York and Brooklyn Bridge, No. 21 Water street, Brooklyn, N. Y., and endorsed "Proposals for Cable Wire."

W. A. ROEBLING,
Engineer New York and Brooklyn Bridge.

INSTRUCTIONS TO BIDDERS.

1. All proposals must be made upon the form accompanying these specifications, all the blanks of which must be filled.

2. The full name and address of the parties bidding shall be given, and a seal attached to all signatures.

3. The guarantee attached to the bid must be signed by two responsible guarantors, known to be good and sufficient by these Trustees, or certified to be such by some responsible person so known.

4. Parties making bids are understood as accepting all of the terms and conditions contained in the specifications, the specifications being considered a part of the agreement.

5. The bidder must be a manufacturer of steel wire, and must give satisfactory evidence of his ability to furnish the quantity and quality of wire required, within the specified time.

PROPOSAL.

1876

, the subscriber , do hereby propose to make and furnish all the Steel Wire called for in these specifications, in accordance with all the requirements therein set forth, for the sum of
cents per pound, gold, payable in monthly installments, upon the terms and conditions mentioned in said specifications.

further agree that upon being notified that bid is accepted, and also furnished with the form of contract, will, within ten days thereafter, execute said contract with the Trustees of the New York and Brooklyn Bridge, with good and approved securities, to furnish said wire upon the terms and conditions set forth in these specifications, the same to be embodied in said contract.

To all of which hereby agree.

Witness, [L. S.]

GUARANTEE.

The undersigned, of hereby guarantee that in case the foregoing bid of be accepted, will, within ten days after receipt of contract and notice of the acceptance of said bid, execute the contract with good and sufficient sureties; and in case said shall fail to enter into contract as aforesaid, we guarantee to pay over into the hands of the Trustees of said Bridge the sum of ten thousand dollars, gold.

Signed,

Date.

Witness.

II.

WIRE TESTS.

REPORT OF THE CHIEF ENGINEER ON THE TESTS OF THE SAMPLES OF WIRE.

No. 33 W. 50TH STREET, December 18, 1876.

HON. HENRY C. MURPHY, *President of the Board of Trustees of the New York and Brooklyn Bridge.*

DEAR SIR :

In compliance with your request of the 16th inst., I present the following report on the tests for cable wire.

The samples were presented and tested in conformity with paragraph 16 of the specifications, which says :

"All parties who expect to bid on this wire are requested to send samples in accordance with these specifications, the samples to weigh no less than 100 lbs., and to contain two rings."

The only object of this section was first, to satisfy myself that each bidder could make such wire as was called for in the specifications, and secondly, that each bidder should satisfy himself that such wire could be easily made, and involved no impossible demands.

The testing of these samples was performed by Col. Paine and Mr. Martin.

Details are given on a sheet accompanying this report (marked A). They comprised samples from the following parties : J. Lloyd Haigh, Cleveland Rolling Mill Company, Washburn & Moen, John A. Roebling's Sons Co., Johnson & Nephew, Sulzbacher, Hymen, Wolff & Co., Carey & Moen, and W. T. Henly & Co.

A general glance over the results shows the gratifying fact that pretty much every bidder has been able to reach our requirements, and that if every one has not reached perfection on every test, they have at least shown that on further trial the results can no doubt be obtained.

Where all have so nearly approached excellence it would perhaps be wrong to institute any invidious comparisons among them, but the facts certainly show, that Richard Johnson's Nephew stands at the head of the list, and Mr. Henly at the foot, but even his wire is not far out of the way in some respects, and the other bidders range in various degrees between these two limits.

The appearance of the various specimens present marked contrasts. Many show signs of having been prepared with the greatest care in getting them up, and of being the product of laborious selection and rejections. Others again show signs of carelessness and indifference, as if they had been pulled at random out of a pile, and nothing in this world were easier than to make this wire.

There are a number of facts attending these samples which require comment on my part. I possess no information, either written or verbal, except in a few cases, as to the stock or material of which these specimens are composed, that is, whether they are made of crucible cast-steel, Bessemer or Open Hearth steel, or by some secret process. Neither do I know whether the bidder in his written tender states the material from which his samples were made, or from which he intends to make the cable-wire; of one fact, however, I am certain, that I have no evidence, and in the nature of the case can have no evidence that the successful bidder will make his cable-wire of precisely the same material as shown by the samples here presented. It would be very unwise to accept two specially prepared rings, as an absolute guarantee of the perfection of 6,000,000 pounds. Fortunately this makes no difference to me, as no wire can reach the Bridge that has not satisfactorily passed through the inspector's hands before leaving the manufactory.

I desire to extend my thanks to all who have presented the samples for the zealous alacrity with which they have responded to my request. The amount of labor entailed on each in making experiments in various grades of steel must have been very great, and the results have been most valuable.

Furthermore, modes of treatment have been arrived at, which obviated the use of expensive patent processes, and cheaper grades of steel have been manipulated in such a manner as almost to equal the most expensive ones. All of this, together with the close competition caused by the great depression of business, must have the effect to materially diminish the cost of the wire.

The results of these tests show an average modulus of elasticity of about 1,000,000 in excess of that called for in the specifications. The latter is evidently placed too low by that amount. This difference was owing to the fact that the large number of samples tested prior to writing out the specifications, were almost wholly of curved wire, which showed no true modulus or limit of elasticity.

I will close this report by a cursory review of the tests of the samples submitted:

Mr. J. Lloyd Haigh presented several samples of very good wire, apparently cast-steel, of three different stocks. The tensile strength exceeding the requirements, the elongation very good, the elastic limit up to the mark, the modulus of elasticity admissible. This wire is very straight, galvanizing smooth, the polish, though of no advantage, adds to the appearance of the wire. Some of his samples fully reached the requirements of the bending test—others did not. The diameter at the point of fracture was usually too large.

The Cleveland Rolling Mill Co. presented two rings of very good wire, we do not know of what stock, of high degree of strength and of requisite ultimate stretch, with required limit of elasticity in one ring and a deficiency in the other, owing to its not being as straight. Modulus, high and variable. The diameter at the point of fracture was good, as was also the bending test.

The want of regularity in the galvanizing has been explained, and attributed to their not being fully prepared to galvanize wire.

The Washburn & Moen Manufacturing Co. presented two rings of good wire, stock unknown, of a high degree of strength, but somewhat deficient in stretch. A small, permanent elongation appears, owing to the wire not being quite straight.

The diameter at the point of fracture is considerably within the limit mentioned, and the wire stood the bending test very well. The galvanizing was good.

The John A. Roebling's Sons Co. presented two rings of cast-steel wire, and two rings of Bessemer stock.

The short tests of the cast-steel wire indicated a high tensile strength, while the long tests fell below the requirements. The elongation was deficient in the long tests. The limit of elasticity is high and variable, and the bending tests not satisfactory; galvanizing, rough.

One ring of the Bessemer wire was very good. It was high in strength and stretch, coming within the requirements as to its elastic limits, and favorable as to modulus and decreased section at fracture, and stood the bending tests very well. The galvanizing a little uneven. The other ring of the Bessemer wire was uneven. One short test made at one end came up to all the requirements, except the elastic limit, and fell below in this because it had not been properly straightened. Tests of the other end of the same wire indicated a want of strength. It showed favorable results as to modulus of elasticity and diminution of section at breaking point. The bending test was not as good as the previous piece; galvanizing, rough.

Messrs. Richard Johnson and Nephew furnished two qualities of very superior wire. One quality was represented by a single ring weighing 114 pounds, with the great tensile strength of about 200,000 pounds per square inch, with a large ultimate elongation. The modulus and limit of elasticity were unobtainable. as the wire was made on the usual two feet drum and had not been straightened. It had a curve about five feet diameter. The bending and galvanizing was passable, and the diminution of section good.

The other quality had a strength somewhat above the requirements, with an unusual amount of stretch and diminution of section. The elastic limit and modulus were equally unsatisfactory with the other specimen. The bending test was satisfactory, the galvanizing passable. If this wire had been galvanized straight it would no doubt have met all the requirements.

Messrs. Sulzbacher, Hyman, Wolff & Co. sent two rings of excellent steel wire, having a high degree of strength. One fulfilled all that we require, but the other failed somewhat in stretch, diminution of section at point of fracture, and on the bending test. This wire was quite straight, and exhibited a high limit of elasticity. The modulus of elasticity was somewhat uneven and high.

Messrs. Cary & Moen presented four rings of wire, two of which were very high in tensile strength, coming up to the required elongation, except in one test, but failing in regard to limit of elasticity, on account of some short bends; the wire being generally straight. The modulus of elasticity was quite high, the section at point of fracture large, the bending test was satisfactory, and the galvanizing good.

The other two rings were very uneven as regards strength and stretch, some of the tests going above, and others falling below the requirements. The limit of elasticity and modulus were also uneven, as was also the diameter at the fracture. The bending tests were usually good, and the galvanizing well done.

The irregularities are largely attributable to short bends found in parts of the wire, while other parts were straight and even, owing to imperfect arrangements for galvanizing the wire straight.

Messrs. Henley & Co. furnished two rings of wire which failed in strength, stretch, and so many other particulars, that it is not deemed necessary to make further reference to them.

The conclusions to be arrived at in this whole matter are simply these. If our cables are to be made of the strongest obtainable wire, regardless of cost, we must take some of the finer qualities of cast-steel, of which some samples have been presented; but if we make our cables of wire of the strength and quality called for in the specifications, combined with the minimum cost, then our course is clear; because a few of the samples presented are made of the medium grades of steel, which have essentially reached all the necessary requirements.

The duty of the Trustees is to buy a certain fixed quality for the least money.

Respectfully submitted,

W. A. ROEBLING,
Chief Engineer.

I desire my letter of the 15th inst., to the President of the Board of Trustees, to be appended to this Report, as the views I then expressed are the same as I now hold on this question.

W. A. R.

(The following is the letter referred to in the preceding postscript.)

No. 33 W. 50th street,
December 15, 1876.

Hon. H. C. Murphy, *President Board of Trustees New York and Brooklyn Bridge.*

Dear Sir:

As my opinion will probably be asked on the wire business before the letting of the contract, I should like to give it before my mind can be biased by a knowledge of the bids, of which I am now in total ignorance.

I would premise by remarking that an undue importance seems to have been attached to the testing of the samples accompanying the bids. How it arose I am at a loss to imagine. The only reference thereto is contained in paragraph 16 of the specifications, which says: "All parties who expect to bid on this wire are *requested* to send samples in accordance with these specifications," etc.

There is nothing mandatory or obligatory in this. No intimation that if the sample was not sent the bid would be thrown out. This is as it should be, because we have no positive assurance that any bidder will send all the wire exactly like the samples he sent. If one man's samples were too good he would be sure to reduce his standard, provided he got the contract, and another man, whose wire fell short of the standard, would have to make his wire come up to the mark before any could be accepted.

When I wrote this section No. 16, I had two objects in view; one was that each bidder should, by actual trial, ascertain for himself what would be required of him, so that he would put in a bid with a full understanding of the subject, and could raise no plea of ignorance on this point or that; the other object was, that each man should convince himself that there was no unjust or arbitrary exactions in these specifications which it would be impossible to fulfill.

In paragraph 14 of the specifications, I go still further, and give the manufacturer two months in which to perfect the manufacture of this cable-wire.

I know that nothing can be done perfectly at the first trial; I also know that each day brings its little quota of experiences, which with honest intentions, will lead to perfection after a while.

If I am asked point blank, I shall have to say the wire of Richard Johnson & Nephew was by far the best of all the samples sent with the bids, notwithstanding the fact that it was not straightened.

Placing his at the head of the list, the rest range down with all sorts of perfections and imperfections.

When I drafted these specifications in August, of 1875, I knew the contract was to be given to the lowest bidder, without regard to the quality of the wire, and it was my duty to guard these specifications with tests and restrictions, which, if faithfully followed out, would fully warrant the Trustees in giving the contract to the lowest bidder.

The surety clause of $50,000 is, of itself, a powerful inducement to make the contractor come up to the mark. As for the tests themselves, they have been scrutinized by interested parties, who all bear testimony as to their searching character.

We know that the wire is to be tested at the manufactory, and that none can arrive at the Bridge unless it has passed through the hands of an inspector.

Of all known materials, wire possesses a shape most susceptible of being tested in every direction. If necessary, a whole mile of it could be tested for its elasticity, throughout every foot of its length, without injuring it in the slightest degree. It is not like a huge casting, which may be full of hidden flaws, or like a big gun which bursts at the first discharge.

Even in the process of strand making, every wire is strained from anchorage to anchorage with a load of 400 pounds, which is only a few hundred pounds less than the permanent strain caused by the weight of the whole bridge. What more can be asked than this, I fail to see.

Very respectfully yours,

W. A. ROEBLING.

REPORT OF ASSISTANTS MARTIN AND PAINE ON THE RESULT OF THE TESTS.

PIER 29, EAST RIVER,
NEW YORK, Dec. 16, 1876.

COL. W. A. ROEBLING,

Chief Engineer New York and Brooklyn Bridge.

DEAR SIR:

We herewith present the results of tests made by us in accordance with your instructions, of the samples of wire furnished by parties

A.

TABULAR STATEMENT,

Giving the results of tests made of samples of galvanized steel wire, sent with the bids for furnishing the cable wire for the East River Bridge.

EXPLANATION OF THE TABLE.

Column 1 gives first, the marks placed upon the coils or bundles of wire by the bidders, and which were upon them when received; secondly, "End A, and End B" indicate test pieces that were taken from opposite ends of the same coil; thirdly, wires 1, 2 and 3 indicate the number of pieces taken, consecutively, from the same ends of the coil.

Column 2 gives the strain, in pounds, at which the respective wires broke.

Column 3 gives the relative breaking strain, per square inch, of solid steel section.

Column 4 gives the length of pieces under test.

Column 5 shows the total elongation, or stretch, at the time of breaking, in ten thousandths of the lengths of the piece tested.

Column 6 gives the permanent elongation, in one hundred thousandths of the length of the sample tested, produced by increasing the strain from 1,200 to 1,600 lbs., and shown on reducing the strain to 1,200 lbs.

Column 7 gives the permanent elongation in one hundred thousandths of the whole length of the sample tested, produced by the increase of strain from 400 lbs. to 1,600 lbs., and shown on reducing the strain to 400 lbs.

Column 8 gives the modulus of elasticity in pounds.

Column 9 gives the diameter of the wire at the point of fracture, after the zinc is removed, in thousandths of an inch.

Column 10 represents the bending tests. "Continuous ½ in." indicates that the wire was bent continuously around a rod ½ inch in diameter without breaking; "4—½ in." indicates that the wire was coiled four times around the rod when it broke.

Column 11 indicates the diameter of the curve which a piece of wire would assume when left to lie loosely on the floor.

Column 12 gives the weight of each coil, as furnished by the bidders.

	1	2	3	4	5	6	7	8	9	10	11	12
	Samples.	Ultimate Strain, In lbs. Per Wire.	Ultimate Strain, In lbs. Per Square Inch Steel Section.	Length Tested.	Ultimate Elongation in dec. of length.	Permanent Elongation. From 1200 to 1600 in dec. of length.	Permanent Elongation. From 400 to 1600 in dec. of length.	Modulus of Elasticity. Lbs.	Diameter Steel Section at Fracture. Inch.	Bending Test. Turns — Diam.	Curve in Wire.	Weight of Ring. Lbs.
J. LLOYD HAIGH.	Coil 2—End A—Wire 1.....	3,815	170,628	5 ft.	.0380	.00000	.00000+	29,817,067	.147	½ — ½ in.	Straight.	69½
	" 2 " B " 1.....	3,950	178,728	5 "	.0470	0	0	29,670,495	.152	Continuous ½ in.		
	" 2 " B " 2.....	3,675	166,169	100 "	.0233	.00001+	.00001+	29,552,941	.160	"		
	" 3 " A " 1.....	3,945	174,177	5 "	.0370	0+	.00001	29,047,565	.160	"	Slight Curve.	59⅛
	" 3 " B " 1.....	4,085	181,580	5 "	.0440	0+	0	29,437,311	.160	"	"	
	" 3 " A " 2.....	3,815	167,647	100 "	.0171	0½+	.00001+	28,815,797	.153	"		
	" 6 " A " 1.....	4,010	182,450	5 "	.0400	0+	0+	29,353,968	.156	½ — ½ in.	Straight.	55
	" 6 " B " 1.....	3,835	175,460	5 "	.0270	0	0	29,709,247	.164	"	"	
	" 6 " A " 2.....	4,025	182,058	100 "	.0233	.00001—	.00001+	29,371,233	.154	"	"	
	" 7 " A " 1.....	3,940	176,570	5 "	.0490	0+	0	29,386,675	.155	"	Straight.	54½
	" 7 " B " 1.....	3,835	174,729	5 "	.0370	0	0	29,585,455	.152	"	"	
	" 7 " A " 2.....	3,880	173,881	100 "	.0300	.00001	.00001½	29,290,640	.161	"		
CLEVELAND ROLLING MILLS.	Coil A—End A—Wire 1....	3,900	180,447	5 ft.	.0360	.00002	.00003	28,917,715	.161	Continuous ½ in.	6 feet Diameter	63
	" A " B " 1....	3,845	177,652	5 "	.0400	.00002+	.00002	30,002,233	.138	4 — ½ in.	6 " "	
	" A " A " 2....	3,740	172,984	100 "	.0210	.00002	.00002½+	29,840,187	.149			
	" B " A " 1....	3,985	182,576	5 "	.0400	0+	0+	30,142,026	.144	5 — ½ in.	12 feet Diameter	66⅞
	" B " B " 1....	3,935	181,554	5 "	.0420	0	.00002	29,387,465	.145	Continuous ½ in.	8 " "	
	" B " B " 2	3,805	175,187	100 "	.0215	.00001	.00001	29,896,883	.148			
WASHBURNE & MOEN.	Coil 1—End A—Wire 1.....	3,865	184,019	5 ft.	.0360	.00001+	.00001+	29,757,300	.134	Continuous ½ in.	10 feet Diameter.	71½
	" 1 " B " 1.....	3,755	179,302	5 "	.0170	.00001	.00001	29,384,702	.147	" ½ "	10 " "	
	" 1 " B " 2.....	3,675	175,164	100 "	.0083	.00001	.00001	28,887,006	.133			
	" 2 " A " 1.....	3,715	174,597	5 "	.0300	.00001	.00001+	29,558,346	.142	Continuous ½ in.		58
	" 2 " B " 1.....	3,760	175,955	5 "	.0450	0+	.00001	29,712,146	.137	" ½ "		
	" 2 " A " 2.....	3,620	169,706	100 "	.0250	.00001½—	.00001¼	29,263,483	.140	" "		
SULZBACHER, HYMEN, WOLFF & CO.	Coil B & C—100—End A—Wire 1	3,905	178,996	5 ft.	.0440	0	0	29,900,587	.151	2 — ½ in.	Nearly Straight.	54
	" " " " B " 1	3,725	170,745	5 "	.0500	0	0+	29,383,077	.154	" "		
	" " " " A " 2	3,685	167,807	100 "	.0182	.00001	.00001	29,190,949	.162	1 — ½ in.		
	Coil B & C—200—End A—Wire 1	3,915	179,454	5 ft.	.0400	0	0+	29,103,238	.150	Continuous ½ in.	Straight.	
	" " " " B " 1	3,945	179,833	5 "	.0400	0	0+	30,389,946	.139	" "		41⅓
	" " " " A " 2	3,845	174,913	100 "	.0317	0+	.00001	29,501,251	.154	" "		
JNO. A. ROEBLING'S SONS CO.	Bundle O.											
	Coil 4—End A—Wire 1......	3,985	179,019	5 ft.	.0370	0	0+	29,948,890	.159	½ — ½ in.		69
	" 4 " B " 1......	3,805	174,706	5 "	.0480	0+	0+	30,207,151	.154	½ — ½ "	Nearly Straight.	
	" 4 " A " 2......	3,210	143,816	100 "	.0054	.00001	.00002	29,578,709	.163	4 — ½ "		*
	" 4 " A " 3......	3,150	143,690	100 "	.0045	0+	.00001+	29,184,524	.161	" "		†
	" 5 " A " 1......	3,675	171,098	5 "	.0410	.00001	.00001	30,231,929	.151	4 — ½ "		70
	" 5 " B " 1......	3,845	171,573	5 "	.0345	.00001+	.00001	28,788,619	.158	2 — ½ "	12½ ft. Diameter.	
	" 5 " B " 2......	2,800	125,321	100 "	.00375	.00001—	.00001+	29,195,923	.167			
	Bundle R.											
	Coil 1—End A—Wire 1......	3,940	178,163	5 ft.	.0375	0+	.00001—	29,749,408	.142	4 — ½ in.	12½ ft. Diameter.	54
	" 1 " B " 1......	3,845	178,512	5 "	.0380	.00001+	.00001	29,952,929	.139	Continuous ½ in.		
	" 1 " B " 2......	3,760	173,177	100 "	.0215	.00001	.00001+	29,524,237	.135	" ½ "		
	" 3 " A " 1......	3,575	161,658	5 ft.	.0360	0+	.00003—	29,749,408	.134	Continuous ½ in.		55
	" 3 " B " 1......	3,400	158,073	5 "	.0380	.00001	.00003+	29,057,511	.141	" ½ "	5½ ft. Diameter.	
	" 3 " B " 2......	3,275	150,371	100 "	.0235	.00001—	.00001	29,432,610	.130	1 — ½ in. with curv.		
JOHNSON & NEPHEW.	Bundle A.											
	End A—Wire 1............	4,425	206,170	5 ft.	.0440	.00004—	.00005		.142	Continuous ½ in.	5 ft. Diameter.	114
	" B " 1............	4,055	196,008	5 "	.0430	.00005	.00009		.148	" "		
	" A " 2............	4,305	199,884	100 "	.0310	.00007	.00016		.143	" "		
	Bundle B.											
	Coil 1—End A—Wire 1......	3,475	166,534	5 ft.	.0590	.00007	.00009		.135	Continuous ½ in.	5 ft. Diameter.	54
	" 1 " B " 1......	3,415	164,836	5 "	.0620	.00005	.00012		.131	" "		
	" 1 " A " 2......	3,515	168,150	100 "	.0540	.00005+	.00010		.129	" "		
	" 2 " A " 1......	3,485	166,301	5 ft.	.0690	.00005	.00009		.134	" "		53
	" 2 " B " 1......	3,465	163,027	5 "	.0630	.00008—	.00014		.139	" "		
	" 2 " A " 2......	3,540	168,445	100 "	.0504	.00006	.00010		.140	" "		
CAREY & MOEN.	Bundle D.											
	End A—Wire 1............	2,755	129,675	5 ft.	.0075	.00002	.00002	29,418,025	.133	Continuous ½ in.	Bends.	46
	" B " 1............	3,985	188,109	5 "	.0420	.00001+	.00002	31,261,041	.155	" "	"	
	" A " 2............	2,700	126,814	100 "	.0058	.00013	.00014		.125	" "	Irregular Bends.	
	Bundle E.											
	End A—Wire 1............	4,215	194,227	5 ft.	.0380	0	.00001	29,922,078	.146	" "	Nearly Straight.	35
	" B " 1............	4,125	191,151	5 "	.0310	.00001	.00001	30,051,705	.154	" "	" "	
	" B " 2............	4,085	190,843	100 "	.0225	0+	.00001	29,813,625	.153	" "	" "	
	Bundle F.											
	End A—Wire 1............	3,175	150,304	5 ft.	.0100	.00001	.00002	30,229,802	.138	" "	" "	49⅛
	" B " 1............	3,825	180,256	5 "	.0350	0+	.00002	30,740,887	.151	" "	" "	
	" A " 2............	2,945	137,918	100 "	.0045	.00001	.00002	29,546,536	.153	" "	" "	
	Bundle G.											
	End A—Wire 1............	3,785	177,143	5 ft.	.0360	0+	.00002+	30,194,381	.153		" "	41
	" B " 1............	3,780	175,022	5 "	.0390	0+	.00002+	30,046,872	.155	6 — ½ in.	" "	
	" A " 2............	3,705	173,090	100 "	.0234	.00001+	.00001+	29,662,190	.160		" "	
HENLEY.	Bundle 1—End A—Wire 1......	3,425		5 ft.	.0130						5 ft. Diameter.	
	" 1 " B " 1......	3,305		5 "	[illegible]						5 ft. "	
	" 2 " A " 1......	3,365		5 "	.0340							
	" 2 " B " 1......	3,325		5 "	.0250						4 ft. "	
	" 3 " A " 1......	2,800		100 "	.0090							

DECEMBER, 1876.

* Slipped in jaw. † Slipped at 1,600 lbs.

C. C. MARTIN,
W. H. PAINE,
Assistant Engineers.

who have presented proposals to furnish the Steel Cable-Wire required for the construction of the East River Bridge, as called for by the published specifications.

We have endeavored to make the tabulated results so full and complete as to obviate the necessity of writing out a long detailed statement.

All of the parties proposing to furnish this wire were present, in person or by representatives, during all or a portion of the time employed in making these tests, excepting Mr. Henley.

A few tests of Mr. Haigh's wire were made before the general invitation to all the bidders was given. The results of these tests are submitted on a separate sheet,* as another complete set of tests of his wire were made in the presence of the other bidders, and are included in the tabulated results.

All of which is respectfully submitted.

C. C. MARTIN,
W. H. PAINE.

B.

Test of Steel Wire received from the Chrome Steel Company.

Designation.	Feet, per lb.	Ultimate Strain		Length Tested.	Total Stretch in dec. of Length.
		Per Wire.	Per Square In. Steel Section.		
		lbs.	lbs.	ft.	
Wire 1.........	10.97	4,350	160,632	5	.032
" 2.........	10.82	4,400	160,208	5	.025
" 3.........	10.83	4,420	161,146	5	.034
Coil X, Wire 1.	11.77	4,050	160,472	100	.0106
" Y, " 1.	12.17	4,155	170,150	100	.0190
" Z, " 1.	11.87	3,770	150,657	100	.0155

No reliable modulus or limit of elasticity could be obtained on account of curve in wire.

Tests made March, 1876.

C. C. MARTIN,
W. H. PAINE,
Assistant Engineers.

* Not printed.

NOTE.—From information subsequently obtained, the character of the steel from which the various samples of wire tested were made, is believed to be as follows:

J. Lloyd Haigh—English crucible cast-steel.
Cleveland Rolling Mill—Open Hearth steel, of their own manufacture.
Washburn & Moen—English crucible cast-steel.
Sulzbacher, Hymen, Wolff & Co.—Sample marked B and C 100: Krupp's Bessemer steel. Sample marked B and C 200: Krupp's cast-steel.
John A. Roebling's Sons Co.—Bundle O: Crucible cast-steel. Bundle R: American Bessemer steel.
Johnson & Nephew—English crucible cast-steel.
Carey & Moen—English crucible cast-steel.
Henley—English crucible cast-steel. (?)
Chrome Steel Co.—Crucible cast-steel, of their own manufacture.

III.

REPORTS

OF

ASSISTANT ENGINEERS

AND

MASTER MECHANIC.

GENERAL REPORT. 1875—1876.

COL. W. A. ROEBLING,

Chief Engineer of the New York and Brooklyn Bridge.

DEAR SIR:

As no reports from the Engineering Department were printed last year, I herewith submit a summary of the general progress of the work on the bridge for the past two years.

Beginning at the Brooklyn Anchorage, as first in order, I would state that this structure was practically finished a year ago, so far as it can be until the cables have been made. The work done this year has consisted in cleaning out and pointing the joints of the arches; trimming the corners and arches, and cutting a "wash" on the offset. The cost, including the amount paid for 274 yards of limestone stored for future use, has been $7,486.31.

During the season 101,909 pounds of anchor bars and pins have been received and placed in position at a cost, including labor, of $7,023.45.

The final estimate on the chains and plates for both anchorages shows a saving on the whole over the estimate of last year of $1,067.70.

The large engine and boiler that were used for the main hoist in building the Brooklyn Tower, have been removed to the anchorage and placed in position for running the cable-making machinery, which machinery has also been put in place during the year.

This work has been in charge of Assistant Engineer Mr. G. W. McNulty. Reference is here made to his report for detailed information concerning the work done in 1875. He has had entire charge of that portion of the Anchorage which is above ground, and has done the work rapidly and well, especially when the many hindrances due to slow deliveries of stone and other materials are considered.

The engines, tools, derricks, supplies and materials, aside from cable-making machinery, but including present value of railroad, stored at the Anchorage yard, inventory at $15,875.

No work was done at the Brooklyn Tower and yard during 1876, except in connection with preparations for cable-making. The report of Assistant Engineer Mr. F. Collingwood, on the work done during the previous year, indicates some of the troubles and dangers encountered in prosecuting the work. The completion of the tower from about the roadway to the top was entrusted to him, and as the pioneer in having to meet all the untried difficulties in construction at this height, he is deserving of great credit for the entire freedom from accident and the success of the work. The stone stored here are already charged to the several structures for which they are designed; aside from these, the machinery, engines, derricks, tools, supplies, materials and office furniture on hand, together with the stone scows, inventory at $21,037.

A large amount of work has been done in the Engineer's office in the preparation of drawings and the necessary computations for the foot-bridge and cradle-ropes, and of designs for the New York approach. This work has been efficiently done by Mr. Wm. Hildenbrand.

A large number of maps of property have been made by Mr. B. G. Lingeman, who excels in this class of work.

Mr. McNulty has spent all his available time in the office in making the drawings of attachments for the temporary, and also for the permanent cables, of the machinery for strand and cable-making, in miscellaneous computations and other work, and *especially* in designing machinery for propelling the passenger cars on the bridge.

Since the stone yard at Red Hook was closed up, Mr. Vanderbosch has rendered valuable assistance on the designs for the New York approach.

To Mr. O. P. Quintard, the gentlemanly and efficient Book-keeper and Secretary of the Board of Trustees, the Engineer's Department is under great obligations for the cheerfulness with which all information required from his department has been furnished.

Mr. J. C. Moore has held the position of Receiving Clerk and Time-keeper during the last two years, and has performed his duties in a highly creditable and satisfactory manner.

The report of Col. Paine covers the operations at the New York Tower for the past two years. During that time 7,356 cubic yards of masonry have been laid, and everything got in readiness for cable-making. The large amount of stone-cutting to be done this year to prepare beds for the saddle-plates and grooves for the long bars, also in dressing up the V course at the springing of the arches, has considerably increased the labor on this portion of the masonry. The estimate for completion, however, shows a slight saving over that made last year, and everything indicates a faithful and economical prosecution of the work.

In addition to his other duties, Col. Paine has, by your direction, continued the admirable series of tests on steel wire. These are probably more complete and accurate than any that have ever preceded them, advantage having been taken of the very favorable facilities offered by the tower for testing in lengths of 100 feet. This has given a knowledge of the material which no short tests could possibly yield, *particularly* of the deleterious effects of coiling the wire in small coils when in a heated state at the time of its manufacture.

The operations at the New York Anchorage are fully detailed in the report of Mr. Collingwood. He has had charge of this work from the beginning, and his plans for carrying it out have been closely followed and have thoroughly approved themselves in their execution. It has been really one of the most remarkable pieces of work on record; during 1875 nearly 16,000 yards of masonry were laid in four months, and during 1876, 11,000 yards in three and a half months, notwithstanding the interruptions caused by raising derricks, putting anchor-chains and plates in position, and inserting the numerous bars and attachments needed in cable-making, and for temporary works connected therewith.

This is almost the only case in which we have had sufficient material on hand to allow the work to proceed with all possible dispatch.

As soon as stone-setting was completed, the stone remaining at Red Hook was brought up and stored as follows:

	Cubic yards.
Limestone at Brooklyn Tower yard	388.0
Granite for Brooklyn Tower, at Brooklyn Tower yard	208.0
" for Brooklyn Anchorage, at Brooklyn Tower yard	56.3
" for N. Y. Tower, at Pier 29	230.3
" " Anchorage, at N. Y. Anchorage	68.5
Limestone for N. Y. Anchorage, at N. Y. Anchorage	108.8
Total stone charged to the several structures	1,059.9 yds.

594 yards of Limestone are also stored at the Brooklyn Tower for Messrs. Noone & Madden, being amount sent in excess of contracts; also 63 Granite corners for Messrs. Pierce & Rowe. Arrangements were made with these parties, by which we were to store the stone, and if at any future time we shall use them, they are to be paid for at the then current price.

After storing the stone, the yard at Red Hook was dismantled, all engines, derricks, etc., removed and stored for future use, and the lease of the yard was surrendered, thus cutting off that item of expense.

Now that the yard has been cleared up and the stone left on hand accurately measured, a satisfactory reply can be made to all questions concerning the amount used in the masonry, and one which is capable of *exact* verification.

There have been received on all contracts for

	Cubic Yards.	Average Price per yd.	Total Price.
Granite..........	69,079 $\frac{19}{27}$	\$21.83	\$1,507,706 02
Limestone................	46,556 $\frac{22}{27}$	13.40	623,561 82
Or a total of.........	115,636 $\frac{14}{27}$		\$2,131,267 84
The stone on hand not laid as given above measure	1,059 $\frac{24}{27}$		
Leaving stone actually placed in masonry......	114,576 $\frac{17}{27}$		

A careful computation of the total bulk of the masonry *now in place* (including, of course, the concrete and mortar joints), made by taking the exact dimensions of each piece of masonry, gives the following quantities, viz.:

	Am't now Laid.	Am't to be Laid.	Total when Completed.
New York Anchorage..	25,897 $\frac{1}{3}$	2,986	28,883 $\frac{1}{3}$
Brooklyn Anchorage....	24,132	2,981	27,113
New York Tower......	46,700 $\frac{1}{2}$	243 $\frac{1}{2}$	46,944
Brooklyn Tower.......	37,995	220	38,215
Totals...........	134,724 $\frac{5}{6}$ yds.	6,430 $\frac{1}{2}$ yds.	141,155 $\frac{1}{3}$ yds.

	Cubic Yards.
Total amount of masonry as thus found to be now laid......	134,724 $\frac{5}{6}$
Total *stone* used in masonry as shown by previous paragraph	114,576 $\frac{17}{27}$
Excess of *masonry* over *stone used*.....................	20,147 $\frac{2}{9}$

It is thus shown that the mortar and concrete spaces make up about 15 per cent. of the total mass. This also explains *another* fact, viz.: that in the first contracts made, where the spaces were estimated at only 10 per cent., there was always an excess of stone beyond the amount required.

It may be of interest to insert here a summary of all the materials used in concrete and mortar for the whole work.

	Cubic Yards.
The total contents of masonry joints as found above are..........	20,147
The concrete filling in and around the caissons, and in the well-holes aggregate about..................................	14,883
Making a total of.......	35,030

The exact amount of material required for this it is impossible to accurately estimate, but making due allowance for shrinkage, it would be approximately 57,000 yards of sand, gravel and broken stone. Of this there were bought,

75,119 barrels of cement, costing	....	$116,740 98
24,328 yards of gravel,	"	41,218 18
4,098 yards of stone,	"	4,764 69
8,735 yards of sand,	"	7,594 17
Total, 37,161 yards of material aside from cement	.....	$170,318 03

This shows that about 20,000 yards of sand, gravel, stone and brick were saved from the several excavations. The value of the material thus saved and utilized is at least $25,000.

The progress thus far made in putting up the temporary work for use in making the cables, is fully detailed in the report of the Master Mechanic, Mr. E. F. Farrington.

The severe storms of the season make the progress slow at present, but without doubt, the foot-bridge, cradles and appendages, will be in position in time to enable work upon the cables to be started in the early spring.

The amount expended this year on this branch of the work for labor and all contingent expenses, has been $94,056.42.

In addition to preparations for cable-making, Mr. Farrington has had charge of the carpenter work and of the blacksmith shop.

The amount expended during the past year for real estate, has been $439,031.24. This includes all legal expenses paid during the year, in connection with these and other land purchases, and all repairs of buildings. With the exception of a few pieces yet to be taken, this covers the entire cost of property between the tower and anchorage on both sides of the river, which remained to be taken at the beginning of the year. The considerable saving thus far made seems to indicate that the estimate of 1873 for the cost of all the land would in no case be exceeded.

I cannot close this report without a word in reference to the work at the Red Hook stone yard. Since we have occupied that yard, about 116,000 cubic yards of stone have been received, and they have varied in weight from one to eleven tons each. They have been unloaded from the vessels, which brought them from the quarries, and stored in the yard; and as they were required for the work they were taken from the piles in which they had been placed, and loaded upon scows. This made four times at least that each stone was lifted, and many of them several times in addition, owing to the fact that the stone were never delivered exactly in the order required by the contract All of this work, which would at a low estimate amount to handling 500,000 cubic yards of stone *once*, has been done without any accident worth mentioning, either to men or machinery. The yard has been in charge of Mr. Frank Mollard, to whose constant watchfulness and knowledge of this kind of work, this immunity from accident is largely, if not entirely, due. All of the stone received have been measured and inspected by Mr. Wm. Vanderbosch; and, although his inspection, in some cases, seemed to the contractors to be too severe, yet his knowledge of the quality of stone and the requirements of the specifications, coupled with his evident desire to deal justly, has in the end satisfied all parties. His difficult and delicate task has been conscientiously and faithfully performed.

With regard to the future work of cable-making, I think I may safely say that no difficulty need be apprehended in securing the services of men to go anywhere or do anything. In the suspended work thus far accomplished, there has been a spirit of rivalry among our best men as to who should be assigned to the most dangerous and difficult tasks; and Mr. Farrington has had constantly to hold them back to prevent their taking dangerous but unnecessary risks. During the year Mr. Thomas G. Douglas, General Superintendent of Masonry, died. He had held that position from the commencement of work on the masonry—having set the first stone on the Brooklyn Tower—and he lived to see nearly the last stone set on the New York Tower, and the towers and anchorages grow into their present grand proportions.

Wm. Conners, a foreman of masons, who built a considerable portion of *both* towers, also died during the year.

The organization of the working force for the season has not been essentially changed.

Mr. C. W. Young still holds the position of General Foreman of labor, and Mr. A. H. Smith is Foreman of the machine shop. We seem to have the right men in the right places, for the work has moved forward rapidly and with very little friction.

Respectfully submitted.

C. C. MARTIN,
Assistant Engineer.

BROOKLYN, December 31, 1876.

BROOKLYN TOWER. 1875.

COL. W. A. ROEBLING,
Chief Engineer of the New York and Brooklyn Bridge.

DEAR SIR:

I would respectfully submit the following report upon the work done on the Brooklyn Tower during the season of 1875:

The work on masonry closed December 12, 1874. Immediately afterward the saddle-plates were taken to the top of the tower, and a force of stone-cutters set at work preparing the beds for them. This work was finished early in January.

During the winter the arch centres were all removed, and the material which was useless for general purposes) was afterwards taken to the New York Anchorage, for use in the foundation of that structure

Regular work on the tower began about the middle of April, when the saddle-plates were set, and the saddles hoisted and moved to their places. Every stone was then set that could be before cable-making, the roof joints caulked, and the work brought to a close about the middle of June. In order to avoid the errors of dimension which were sure to creep in from irregularities in stone-cutting, and running up masonry to this great height by the use of the plummet and line only, frequent measurements of the exterior lines were made, and all referred to central transit lines, which were themselves referred to points fixed upon distant buildings. Levels were also made over the whole surface, and transferred by vertical measurements to a bench mark in the yard below. By this means the joints were kept to their proper thickness, and we were enabled, by a minimum amount of stone dressing, to set the saddle-plates at exactly the height required. In setting the archstones every piece of lagging for them was put in position by level and measurements from transit lines.

The finishing up of the masonry was a work of considerable difficulty and danger, as many of the roof stones weighed from nine to ten tons each (the key-stones weighed eleven tons each); and it was difficult to properly support the derricks, which were not balanced to support so great a weight.

The risk was considered so great, that one of the engineer corps was in constant attendance whenever stone-setting was being done.

One other cause of danger arose from the great length and weight of the hoisting ropes of the main hoist. These were steel wire ropes 1½ inch diameter, and had reached lengths from the drums to the sheaves at top of the tower of 350 feet each. The vibrations in them caused by the pulsations of the engine frequently became so violent as to require a stoppage or change of motion of the latter.

The final effect was a succession of surges on the stone, requiring extra care in the attachments for hoisting. For this purpose extra large lewises were used, and a very careful man was placed on the scow at the base of the tower to examine all the holes and drive the lewises. In spite of this care, however, the granite failed in a few instances, spalling out for two feet around the hole. In only one case did a stone fall. This was after reaching a height of 200 feet. It did no damage beyond completely demolishing the tracks underneath and burying itself in the ground.

One of the greatest difficulties experienced was that of making effective signals to the engineer in the yard below, so as to prevent overwinding. Sound was often of no avail owing to the high wind; sight was sometimes partially obscured by fog, and signal bells were constantly out of order from the wires getting broken.

The attachments on the tower were all made abundantly strong, and, although a few cases of overwinding occurred, no accident resulted in consequence.

The most effective signals were found to be a loud whistle to call attention, and a flag used with a very positive motion to indicate what was required.

It is a great satisfaction to be able to state that, during the building of all that portion of the work which is above the roadway (by far the most difficult part), there has been no accident to life or limb.*

A narrow escape occurred whilst transferring the last of the saddles from the elevated track at top of the tower to the masonry. This was done by the traveling crane; and while the weight of 13½ tons was suspended just over the edge of the masonry, the hook of the upper block began to straighten. It stopped fortunately after opening an inch, and the saddle was quickly lowered and secured.

The application of steam to the setting derricks has saved a considerable amount of time, and no difficulty was found in carrying the steam to the top of the work, requiring a length of about four hundred feet of pipe.

The trestling and stairway have been carried to the extreme height that will be required. The hoisting frames have been removed, and the top cleared of all obstructions.

The amount of masonry set during the year is 497 yards, leaving 220 yards to be set after cable-making to complete the tower, aside from parapets.

The total expenditure on masonry, including stone on hand for completion, has been	$32,348 55
A further sum has been expended at this yard for repairs of dock, watchman, stableman, messenger, etc., of..........	2,839 34
The four saddles weighing a total of 103,423 lbs., the four plates weighing 81,595 lbs., and 180 rollers weighing 25,260 lbs., including the labor of preparing, hoisting and placing them, have cost a total of......................	10,701 17
This is a saving of nearly $1,800 on the estimate of 1873.	
The machinery and material at the Brooklyn Tower and yard, together with the furniture in the offices, inventory at ...	32,486 70

I ought not to close this report without a brief statement respecting its stability as thus far shown. When the masonry was but a few feet

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* This result has only been secured by incessant watchfulness on the part of engineer and foreman. On one occasion four men were pulling on a tackle with their backs to the edge of the wall. They were told to change about, so that in case anything broke they would be safe from harm. Almost immediately after straining up again, the hook of one of the blocks straightened. Had this happened at first they would have inevitably been precipitated over the edge of the masonry. Sudden gusts of wind of great violence required a constant watchfulness to prevent being blown off the wall by losing balance when near the edge.

above high water, reference marks were fixed in the masonry at four feet above tide at each of the salient angles and levels, carefully made upon them, and referred to a stationary bench mark on a building some distance away. Recent levels have been made upon the same points and they show an average settlement caused by the mass of masonry added, of only $1\frac{1}{4}$ inches, with an extreme variation between any two points of only $\frac{1}{4}$ of an inch.

Respectfully submitted,

F. COLLINGWOOD,
Assistant Engineer in charge.

BROOKLYN, December 31, 1875.

N. Y. TOWER. 1875-1876.

COL. W. A. ROEBLING,
Chief Engineer of the New York and Brooklyn Bridge.

DEAR SIR:

I have the honor to present the following report of such operations connected with the construction of the East River Bridge as have been entrusted to my charge during the past year, and also a condensed statement of the report made to you respecting the work done in 1875:

The work of laying masonry on the tower was resumed April 30, 1875, at the point where it closed in the previous December, being at the top of the 120th course at the springing of the arches, $196\frac{64}{100}$ feet above mean high tide.

There were two long and vexatious delays, amounting in all to 82 working days during that season. These were caused by the stone contractors not being prompt in the delivery of stone. The work of stone-setting for that season was finally suspended on the 27th of November for the same cause, at the top of the 139th course, being the top of the key-stones of the arches, and had a height above tide of $239\frac{84}{100}$ feet.

The height laid during 1875 was $43\frac{20}{100}$ feet, leaving $31\frac{46}{100}$ feet to complete the tower, requiring about ten weeks of uninterrupted work—a less space of time than had been lost by delays.

The quanity of masonry laid during the season was 3,806 cubic yards, using 3,385 cubic yards of stone.

The total cost of masonry for the season, including labor, material and all expenses, was........................	$105,994 70
The end of the dock was repaired at an expense of........	461 03
The saddles and saddle-plates were on the dock and ready to be placed in position. Their total weight is 183,107 lbs., and their cost was................................	5,949 27

There were 65 yards of granite for use on tower stored here and at Red Hook, which had been paid for, aside from a large quantity at Red

Hook received, but not then estimated for on account of the courses not being completed.

The value of other materials, supplies, machinery, tools, and furniture in this yard, inventoried at..............	$36,760 85
The estimated cost of completing the tower was..........	136,800 00

All of the masonry above high tide had been carefully examined during the year, and rejointed where it was necessary. A considerable force of carpenters had been employed in erecting the arch centres, removing the traveling crane and erecting a balance derrick on the centre shaft; also in building up the scaffolding as the work progressed.

Passing from the work of 1875, the masonry of the New York Tower, which at the close of that year had reached a height of $239\frac{84}{100}$ feet, has during *this* year been finished, excepting the parapets and such portions of the three upper courses as could not be laid without interference with the cable-making.

The present height of the tower to the top of the roof course is $271\frac{3}{10}$ feet, making a height of $31\frac{46}{100}$ feet laid this year. The amount of masonry laid has been 3,550 cubic yards.

The work of laying the masonry was resumed on the 11th of April, a small amount of stone-cutting having been previously done. Only one gang of masons was employed during the season, and they were often delayed by the stone-cutting required to be done.

The stone-setting was completed on the 24th of July, after which time several masons and stone-cutters were employed until November 13 in trimming and pointing all the masonry of the tower that remained unfinished.

I ought here to express my gratification at the manner in which the work on the tower has been done.

Mr. D. J. Cowan proved himself to be a competent, careful and reliable foreman of masons.

Mr. Harry Supple was all that could be desired as foreman of riggers and laborers on the tower, while Mr. O. B. Poor showed his capability of taking charge of the men variously employed upon the dock.

The total amount expended during the past year on masonry, including a due proportion of all office and contingent expenses, and the stone stored for future use, has been....	$121,979 90
The amount previously expended was....................	1.040,065 00
The total amount expended to date, is	$1,162,044 90
The estimate as revised last winter, was..................	1,176,865 00
Leaving amount of estimate unused	$14,820 10
The estimated cost of completion from this date, is	14,778 00
Showing a small saving on estimate of Jan. 1, 1876, of....	$42 10

The amount of masonry yet to be laid, is 243½ yards, for which the stone are now stored at this yard.

The machinery, tools, supplies, furniture, derricks, etc., on hand at this yard (not including stone stored for future use), inventories at $25,113.

It is here proper to call attention to the fact that the stone and all other materials required during the past two years for the construction of the New York Anchorage, have been received at this pier, giving an opportunity of employing all the labor economically.

The blacksmith and machine work for the Anchorage and for cable-making have also been done here.

During the past four years I have endeavored to carry out, as fully as circumstances would permit, your instructions in regard to experiments with and tests of wire, and have conducted them with the objects which you desired, kept in view.

The experiments relative to the properties requisite in the cable-wire to meet all that will be required of it, have been made with great care; while the tests of wire for the purposes of ascertaining the possibility of meeting these requirements, have been very large in number, and comprehensive in their range, and have occupied much time.

Besides the wire that has been directly ordered of different parties in this and other countries, many other samples have been received from a large number of different manufacturers. Added to this, the testing of all the wire, used in making the foot-bridge ropes, which now span the river, has given unusual opportunities of becoming acquainted with all the properties of steel wire, that can be practically obtained and relied upon. The experiments and tests have been conducted with a view of harmonizing that which is *desirable*, on the one part, with that which is *attainable* on the other, in a practical and economical manner. Full and complete records have been kept of the results of all the experiments and tests that have been made. As the results have been placed before you, from time to time, and I have all along been guided by your instructions, I need not further dwell on this subject, than to express my satisfaction, in regard to the fact, that although the specifications call for wire, in some respects superior to any ever before produced, they have been met so fully by the samples presented by bidders. In all this work I have been ably assisted by Mr. C. H. Platt, who, from his knowledge of engineering, has rendered aid of every character, for which I had occasion to call upon him.

Very respectfully submitted,

W. H. PAINE,

Assistant Engineer.

NEW YORK, December 31, 1876.

NEW YORK ANCHORAGE. 1875–1876.

Col. W. A. Roebling,

Chief Engineer of the New York and Brooklyn Bridge.

Dear Sir:

I would respectfully present the following report as to the work thus far done upon the New York Anchorage, beginning with the report written a year ago upon the work of 1875.

The property upon which the Anchorage stands was paid for early in April.

Full possession was not obtained until the 6th of May, when the demolition of the buildings, and the excavation for the foundation were at once entered upon.

Owing to the late letting of the contract for material for the railroad through Roosevelt and Water streets, the work of laying down the tracks could not be started until May 28th. It was completed by June 21st so that dirt cars could be run over it to Pier 29, and a week later all hauling with carts was stopped.

The temporary hoisting derricks were ready for use June 19th, and the work of sheeting and bracing the banks of the pit began at the same date. The work of bringing the material for this, and for the permanent structure to the Anchorage, was very much facilitated by the railroad.

The tracks run almost entirely through narrow streets, but by a judicious use of curves and switches, all serious stoppages even during business hours have been avoided. The cost of the railroad was about $6,000, being considerably less than the estimate.

By June 21st the excavation had so far progressed as to make it necessary to begin pumping to free the pit from water.

At first, two No. 4 Niagara pumps were used, but by July 3d it became necessary to add an Andrews' centrifugal pump.

From this date for four weeks, the quantity of water thrown out averaged about 600 gallons per minute. Pumping finally ceased August 21st.

The actual work of excavation was very expensive, owing to the massiveness and solidity of the numerous foundations to be removed. In some of these the cement was so solid as to make it necessary to break them up with sledges.

I estimate the quantity of stone and broken brick saved (aside from the brick sold) to have been about 1,100 yards. This has more than supplied all the materials of the kind needed thus far, for the vertical spaces in the masonry.

The sand and gravel saved was but 1,000 yards; the remainder of the excavated material being totally unfit for use.

This was quite contrary to previous expectations.

A considerable saving was made in the amount of sheeting required, by allowing the basement walls along Dover street to stand until after the foundation was completed.

An additional saving was made by giving wider spaces between the braces than was adopted at the Brooklyn Anchorage.

This, with other modifications, gave much freer working room, and greatly facilitated subsequent operations.

The present bulkhead line on the East river is about 600 feet, in advance of the old shore; the intervening space having been filled in and covered by blocks of substantial buildings. Our excavation showed that the old shore line passed directly across the Anchorage site, but was not so regular in outline as previous examination had lead us to infer.

At the corner nearest Dover and Water streets, the clear sand below the mud was found at about 7 feet below mean high tide. At this point a large quantity of spent tan bark had in time past been dumped into the water, on top of which was the ordinary dirt filling. This was no doubt the refuse from the tanneries, so long ago established in the "Swamp." For the rest of the distance across the front the average depth was about 5 feet below tide.

At about the centre line of the excavation, and also on the east side, there were indentations running back to near the centre of the pit. One of these was entirely filled with peat, which must have grown when the island was in its native state.

At about the depth of high water, an old dock, long since buried, was uncovered. This ran entirely across the pit, and the front edge was nearly parallel with Water street, at about thirty feet from it. It was about twenty feet wide, and four feet deep. The logs composing it were from six inches to thirty inches in diameter, and were all *perfectly* sound after their long burial.* As they extended under the sheeting at both sides, and had to be cut off under water, they caused a great deal of trouble in driving the planks.

A large number of pieces of fossil coral were found in front of the dock; this is supposed to have been ballast. which was thrown overboard from vessels previous to the river being encroached upon. In the course of the excavation two four-pound cannon balls, whose history would no doubt be of interest could it be told, were found buried deep in the sand.

Before beginning the foundation, every particle of mud and other compressible material was removed. As the mud ran deeper than had been anticipated, it was deemed advisable to extend the timber grillage at the front, about eight feet in advance of the original plan. In addition to this, the grillage was by your order placed four feet lower than that of the Brooklyn Anchorage, or so that the top of it was level with high tide. By these and other changes, the quantity of excavation was increased

* As a proof of this, some of them were used afterward in bracing the foundation under end pressures of seventy tons, on sticks 14 x 14 x 25 feet.

about 2,500 yards, and the quantity of masonry about 2,000 yards, over previous estimates.

The sheeting across the entire front and east side, and partly across the other side and end, was driven to two feet below the foundation, and allowed to remain, as a further precaution against possible settlement.

Care was taken with all the back filling, to allow none but selected material to be dumped; and all was thoroughly compacted by a water jet as it was thrown in. This was all brought from other works, without cost to the bridge.

The first timber of the foundation was placed June 12th, and the last dirt sent to the dump June 14th.

The total quantity of excavation was 12,761 cubic yards, and the total cost per cubic yard was $\$1\frac{21}{100}$. This includes tearing down the walls of a part of the buildings, and all of the foundations, sheeting and bracing, pumping, all labor at the pit and dump, all hoisting and transportation of material, the hire of mud scows, and the cost of tools.

In constructing the grillage, the deep space in front was entirely filled by partial courses of timber firmly bolted, and with concrete filling in the spaces, which were made wide for that purpose. A level surface over the whole foundation was reached at four feet below tide, and from this point the regular courses of timber were started according to the original plan. The first of these was the bearing course, with three-inch concrete spaces where it rested on the partial courses, and nine-feet spaces, filled with sand, where it rested on the sand. The second course had one-inch cemented spaces; the third had three-inch concreted spaces; and the fourth, or top course, had six-inch ditto. The bolting was systematic and thorough, about 10,000 bolts 20 inches to 30 inches long, of $\frac{7}{8}$ inch iron, with an aggregate weight of 19 tons, having been used.

The cubical contents of the foundations are about 1,840 yards, and the cost per yard was $\$11\frac{48}{100}$ for material and labor. This would have been about $1 more, had new timber been substituted for the old centres and other waste timber, which made up a part of that used.

The work of erecting the six permanent setting derricks was begun August 14th, and completed on the 28th. The foundation was, however, completed on the 9th, and stone-setting begun on the 5th over that portion of the foundation then finished. This was done to save time, and about 1,400 yards were thus set before the permanent derricks were ready.

By August 31st everything was in readiness for the anchor-plates to be put in place; but owing to the delays in awarding the contract for them, the contractors found it impossible to deliver the first two earlier than September 7th, and the remaining two did not arrive until the 25th. This largely increased the labor of setting them, by making it necessary to raise them above the masonry which had meantime been laid, and to lower them into the holes that had been left for them, which were about 16 feet deep.

In bringing the plates from Pier 29, the railroad was brought into use with a considerable saving of time and expense.

For this purpose a heavy framework of timber was made strong enough to support the weight (23 tons) of each plate, and of a length of 30 feet, or sufficient to span the space between the centres of two cars, when the plate hung freely between them.

The frame was pivoted at each end, and rested on heavy oak bolsters, so as to allow the cars to take the railroad curves easily.

As a precaution, the curves, one of which had but 34 feet radius, were soaped before starting.

The plates were 17½ feet by 16 feet in size, making it necessary to remove a lamp-post and some other obstructions.

When all was ready, three teams of horses were attached, and the heavy weights were each taken over the 1,000 feet of track between the pier and anchorage in from 1½ to 2 minutes.

September 23d the masonry had been brought entirely above ground, all the sheeting (except that heretofore mentioned) had been withdrawn, and everything was in regular working.

A night gang of laborers was organized June 21st to facilitate the excavation, and continued for this and other purposes throughout most of the season. About the middle of September a night gang of masons was put on. The experience has been that such work as concreting, and the rougher parts of mason work can be done more economically at night, owing to entire freedom from delays in the transportation of material.

By November 4th the masonry had progressed so as to require the derricks to be raised 28 feet.

This work was so thoroughly systematized as to cause a delay of but 8½ days.

During the season three sets of anchor bars were put in place. Thorough inspections have been made from time to time of the iron used, and it is gratifying to state that the quality is even better than that prescribed in the specifications for them. Stone-setting was brought to a close for the season on December 11th, at a height of 44½ feet above tide.

Notwithstanding the fact that the work has been pushed to the utmost, but few accidents have occurred, and none of these were of a fatal character.

The total quantity of masonry laid this season is 14,892 cubic yards, at a cost (for labor, superintendence, material, supplies, ⅓ cost of railroad, and *all* contingencies) of $\$14\frac{32}{100}$ per yard, or $\$3\frac{29}{100}$ less than the estimate of 1873, the total cost being $\$213,290\frac{92}{100}$.

To balance this saving the whole anchorage will contain, as stated, 2,000 yards more masonry than was contemplated in 1873, of which 1,600 yards belong to the portion now in place.

This, with the large increase mentioned in the quantity of excavation, and the increased cost due to the many obstructions met with, have very nearly balanced the saving on the estimate.

The railroad, of which one-third is charged to work of this year, has cost..................................	$5,950 59
The total cost of the foundation, including the excavation, has been..	36,589 24
The anchor-plates weigh an aggregate of 182,855 pounds, and cost in place (a saving of about 40 per cent. on the estimate of 1873)................	$7,631 35
559,900 pounds of anchor-bars have been received at a cost of (about 25 per cent. less than the estimate of 1873)	33,034 10
To which must be added for labor in putting three sets in place...........	1,384 10
Total cost of anchor-bars and plates thus far............	$42,049 55
The estimated cost of completing the same, is............	36,992 00
Total estimated cost of anchor-bars and plates for this anchorage	$79,041 55
The cost of the structure at the end of this season's work, including the total cost of the railroad and of the foundation, but not that of the plates and chains, was.........	253,847 22
The estimated cost of completing the masonry and the roadway........................	248,249 06
Total estimated cost of the structure when complete.	$502,096 28
The machinery, materials, supplies and tools on hand December 31, 1875, at this yard, inventory at............	$19,775 02

The organization of the force employed has been as follows:

The labor gangs have been under the charge of Mr. C. W. Young, assisted by J. D. Irving and Jos. Scheidecker. The carpenter work has been under the immediate supervision of Mr. E. D. Pepper, and the mason work under the care of T. G. Douglas, assisted by foremen C. Lynch, John Cahill and Thomas Kelly. The records of materials received were kept by Mr. Frank Brown.

In the office I have had the aid of Mr. J. A. Kingsley in the care of orders and accounts, of Mr. B. G. Lingeman, as draughtsman, and the very efficient aid of Mr. F. L. Rowland, in the preparation of working plans for the last stone contract, and in the care of the work. All have done their work well.

The work done during the year 1876 is, by your direction, prefaced with a brief description of the structure itself, as follows:

This is a mass which when completed will contain 28,883⅓ cubic yards of masonry. The amount laid during this year is 11,005⅓ yards (or altogether 25,897⅓ yards), leaving 2,986 yards to be set after the cables are made.

The joints in this masonry have been found to aggregate about 18 per cent. of the total bulk.

The whole rests upon a timber grillage four to seven feet deep, the top surface of which is at the level of high tide, and a little below the level, at which fresh water stands in the soil.

The outline of the masonry in plan is rectangular. It is widened at the rear by an offset of five feet on each side, made at 85½ feet from the front. These offsets serve to give greater mass over the outer anchor-plates.

The length over all the base of masonry is 129 feet. The width at the front is 106 feet 4 inches, and at the rear 116 feet 4 inches.

The rear mass is solid, with the exception of two small tunnels 14 feet wide, and 29 feet 7½ inches high to the crown of the arch.

The front and narrower portion is divided by large tunnels into three parallel walls. These are called anchor walls, and receive the pressure from the anchor chains; the two central chains being buried in the middle wall, and one of the others in each of the outer walls. These tunnels are covered over by semi-circular arches of 23 feet span, springing from a height of about 65 feet above tide.

The thickness of the outer walls at the springing is 12 feet, and of the middle walls 26 feet.

All of the faces except those of the small tunnels, and the rear faces of the large tunnels, have a batter of half an inch per foot rise, from about eight feet above tide, and in addition to this there is a wide offset (10 inches) at 22 feet above tide. The courses below the battered portion each step in by wide offsets all around.

There will be a cornice at top similar in design to those on the towers, of a full height of 12 feet 7 inches.

The top surface is to be sloped to the grade of the roadway, of which it will form part, and will have a length of 117 feet and a width of 104 feet 4 inches, and 94 feet 4 inches at rear and front respectively.

The height of the roadway at front will be 89.04 feet, and at the rear 85.24 feet.

The external corners of all courses of stone above the 10-inch offset are granite blocks, with a bold projection, the edges being chamfered off four inches all around and fine cut, and the surfaces being fine pointed.

The cornice and curtain arches in front are also of granite, with a 1½ inch draft around each stone and fine pointed surface. In addition to this, 642 yards of massive blocks of granite weighing five to ten tons each, were placed over the anchor-plates in the first four courses above them, and thoroughly bonded, so as to make the full weight of the masonry above available against any lifting of the plates.

The remainder of the stone used were limestone with a bold rock face.

All limestone were furnished by Noone & Madden, of Kingston, New York.

The first contract for granite was let to Beattie and Dresser, who filled it from their quarries at Stony Creek, Conn. The last contract was with Mr. Joseph Brennan, whose quarry is at Charlotteburg, New Jersey. The stone are slightly pinkish in color, and correspond well with those from Stony Creek.

Stone-setting began this year April 10th, by the day gangs, and April 12th, by the night gang; and was carried on as rapidly as was consistent with sound work. From May 16th to 23d, was occupied in raising derricks, being a less time than the same work has at any other time required.

June 6th, the work of putting up the centres for the main arches began. This made it necessary to get another hoisting engine in position, and from this time all the stone were hoisted at the front of the Anchorage, and run back to the several derricks by cars on a temporary track on top of the masonry.

By July 13th the work had so far progressed that it became necessary to discharge one day gang, and the next day the night gang was discharged.

August 9th to 18th, was occupied in raising derricks for the last time, and placing them on top of the arches. On the 22d all the stone-cutters were discharged; on the 28th stone-setting was completed, and by September 25th the pointing was completed, and all masons discharged.

This part of the masonry has cost more for labor than that done last year on account of the large number of grooves to be cut, and other stone-cutting made necessary by the anchor-bars, and the bars inserted for attaching and securing the temporary cables.

The total expenditure on masonry for the present year (and not hitherto reported), including a due proportion of all office and contingent expenses, and the stone stored for future use, has been.............	$184,405,05
The amount previously expended was....................	253,847,22
The amount estimated as now required to complete the Anchorage is......	59,552,41
Making the total cost for everything except plates and chains	$497,804,68
The estimate as revised last winter was.................	502,096,28
Showing a saving on the summer's work of..............	$4,291,60

The weight of anchor-bars and pins bought during the year is 509,778 pounds, making a total weight of 1,069,678 pounds in this Anchorage.

The total cost of bars and pins in place for the year is.....	$34,469,26
Amount previously expended on plate and bars was.......	42,049,55
Total cost of anchor-bars and plates	$76,518,81
The estimate of last winter was.........................	79,041,55
The *saving* on the estimate is therefore..................	$2,522,74

The organization of the force has been essentially the same as that of last year. I have had the continued assistance of Mr. F. L. Rowland in the general care of the work, and of Mr. J. Mulqueen in the care of office accounts.

The materials, tools, derricks and engines on hand at this yard, and present value of railroad (not including stone stored for future use), inventory at $20,039.92.

A considerable portion of this value will at the close of the work be available as a credit upon its total cost.

The settlement of the masonry at the close of this year's work, as measured at the top of the offset, was an average of $1\frac{1}{4}$ inches, and remarkably uniform. This is no doubt due, as in the case of the towers, to the slightly increased compression of the foundation caused by the increase in weight.

Respectfully submitted,

F. COLLINGWOOD,
Assistant Engineer in charge.

New York, Dec. 31, 1876.

BROOKLYN ANCHORAGE. 1875.

Col. W. A. Roebling,
Chief Engineer of the New York and Brooklyn Bridge.

Dear Sir:

I would respectfully present the following report upon the work done during the past year at the Brooklyn Anchorage.

Previous to the time of commencing work for the season, the masonry of the Anchorage (during 1873 and 1874) had been carried up to 62 feet 2 inches above high water, 26 courses of stone having been laid.

Work was resumed April 6th, and the masonry has been brought up to 78 feet 6 inches above high water, and entirely completed (except some pointing and stone dressing), as far as it can be preparatory to cable-making.

The masonry laid this year was 5,921 cubic yards (using $5{,}314\frac{1}{2}$ yards of stone), and making the total amount thus far laid on the Anchorage 24,255 cubic yards.

Considerable cutting of dim^usion and archstone has been done, in consequence of the contractors having failed to deliver stone on time. This has not been an unusual experience; and although the cutting has been charged to the contractors, the result has been a considerable increase in the cost of the work in consequence of its necessarily irregular prosecution.

Considerable delay was occasioned also by having to leave large holes in the masonry for the insertion of the seventh set of anchor bars, which arrived too late to be put in place at the proper time.

The stone-setting derricks have been raised twice during the season, and now rest on the arches, in proper position for use, as they may be required during cable-making.

The total amount expended upon the Brooklyn Anchorage to date for everything, except anchor chains and plates, is $507,226.74.

The expenditure estimated as requisite to complete the masonry is $62,482.

The 5th, 6th and 7th sets of anchor-bars have been placed in position during the season; also all the bars for anchoring and holding down the foot-bridge and cradle cable; and for use in letting off strands of the main cables. All the bars of the remaining sets have been received except 72 of the 10th. and most of them have been scaled and painted, in preparation for placing.

The amount expended on them during the year, including labor of preparation and insertion, has been..........	$38,335 22
Total amount to date, including $12,361.31 for the plates, has been..	83,295 93
The amount required to complete them will be............	5,568 40

CABLE-MAKING.

After work upon the masonry was stopped, a shed was built covering the top of the Anchorage, for the reception of the cable-making machinery. The drums, wheels and other machinery are now in process of construction, and will all be placed in position early in the spring.

The cost of these various items has thus far been.........	$3,300
The estimated value of machinery, tools, stores and other movable property now in the Anchorage yard, is........	10,122

Respectfully submitted,

G. W. McNULTY,
Assistant Engineer in charge.

Brooklyn, Dec. 31, 1875.

Col. W. A. Roebling,
Chief Engineer New York and Brooklyn Bridge.

Dear Sir:

I am able to report progress in the preparatory work for cable-making which you have entrusted to my charge, as follows. This includes making all the machinery for cable work; getting over the temporary wire ropes, and making the cradles and foot-bridges, and placing them in position.

The cable-making machinery is located on the Brooklyn Anchorage, and it was made on the same general plan as that used in making the cables for the Covington and Cincinnati Suspension Bridge, with some changes to suit local requirements. It is in duplicate, for making two pairs of cables at the same time, and each set is constructed so as to work independently of the other.

The several parts of the running machinery are designated as follows: The driving wheels, the guiding wheels, the sliding beveled gears, the counter shafts, clutches, levers, pinions, segment gearing, and the tightening pulleys.

The driving wheels are two in number, attached to upright wrought iron shafts, which run in cast-iron boxes set in the masonry. These wheels are eleven feet in diameter, and six inches thick; having two grooves around the edge. The guiding wheels are single grooved, fou. feet in diameter, and three inches thick. Three of these, with a driving wheel, form one set; and they all run in the same horizontal plane except the centre one, which is inclined the thickness of the rope. They are so constructed that the working rope, or "traveler," runs on the end grain of the wood. The traveler is so arranged around the driving wheel that the bearing surface is equal to one and one-third times the circumference of the wheel; and this friction has been found to more than equal the power of the driving belt.

A horizontal wrought iron shaft, 3½ inches in diameter, runs on the Front street face of the Anchorage masonry; and motion is given to it by a sixteen-inch leather belt, ninety-eight feet long, leading from the fly wheel of a steam engine, in the yard below. From pulleys on each end of this shaft, 8-inch belts lead to pulleys on two short, horizontal counter shafts, on the top of the masonry. On each counter shaft are two sliding, beveled gears, worked by a clutch and iron lever, so as to give a forward, or reverse motion to another beveled gear, which is fastened on the lower end of an upright iron counter shaft. On the upper end of this shaft is a pinion, which works in gearing, bolted in segments, on the top surface of the wooden driving wheel. Each set of machinery is fixed in a heavy timber frame, which is securely fastened to the masonry. The 8-inch belts run loosely on the pulleys, and the machinery is put in motion, or stopped, by a tightening pulley, worked by a lever, without stopping the engine.

On the New York Anchorage, each traveler runs around two 4-feet wheels, like those in Brooklyn, placed in a sliding frame, which is so arranged that the slack in the rope arising from its stretching can be taken up at any time, without cutting and splicing. All of these wheels are made of oak.

Under the head of machinery, we may also include the drums for holding the wire; the reels and traveling sheaves. There are 32 drums placed in the wire shed which was erected some time since, on the Brooklyn Anchorage. They are 8 feet outside diameter, 16 inch face, with a depth of rim of 6 inches. Their working capacity will be about 50,000 lineal feet of No. 8 wire.

As soon as it is known what the diameter of the coils of wire will be, the reels for holding the same will be made. The "Traveling Sheaves" which are to be used in running out the wire, for the main cables, are 5 feet outside diameter. They are made with six light wooden arms, radiating from a wooden hub, and a light wooden rim 2 inches thick, in the outer edge of which is a V shaped groove, about 1 inch deep. This groove is lined with galvanized sheet iron, which projects 4 inches beyond the wood, thus making the groove about 5 inches deep. The outer edges of this iron are stiffened by having a wire rolled into them, and by thin strips of iron which are riveted at intervals to the outside of the V, and bolted to the wooden rim. Thirty-six holes, 3 by $2\frac{3}{4}$ inches, are cut in the sides of these rims opposite to each other, for the free passage of the wind.

The wire ropes are 17 in number, made of galvanized steel wire. Taken in rotation, their names, sizes and uses are as follows: Four "travelers," $\frac{3}{4}$ inch in diameter, spliced into two endless ropes around the propelling machinery before described. They have been used for hauling over the other ropes, in part, and for hauling the buggies back and forth; but their final use will be to carry the traveling sheaves, when the wire for the main cables is run out.

The next in order is the "carrier," $1\frac{3}{4}$ inch diameter, for holding the weight of the heavier ropes, when they were hauled over the river. Next, 3 cradle cables, $2\frac{1}{4}$ inch diameter, for supporting the cradles, which will be described further on. Two foot-bridge cables, on which a foot walk for the use of the cable workmen, will be laid. These ropes will also support one end of 5 of the 10 cradles. One $1\frac{1}{4}$-inch diameter auxiliary rope, which with the carrier will finally be used to assist in supporting the foot-bridge. Two $1\frac{1}{4}$-inch diameter "storm cables," which will extend from one tower to the other below the roadway, and be attached to the foot-bridge cables by small wire rope suspenders, in the form of inverted cables, to prevent the foot-bridge from being lifted by the wind. Two $\frac{5}{8}$-inch diameter ropes, for hand-rails for the foot-bridge, and 4 "pendulum ropes," $\frac{3}{4}$-inch diameter. These will be used to support small iron rods, having flat leaden weights attached to their lower ends, which will separate the two parts of each strand of the main cable, while they are being laid, and prevent their entanglement by the wind. The travelers, carrier, cradle cables, and the foot-bridge cables are in position. The auxiliary foot-bridge rope, and one storm cable, have been taken over the river. Attempts have been made to attach the suspenders to the storm cable, and to place it in position, but high winds and extreme cold have prevented this from being done. I have arranged swing stagings, or "double buggies," to run on and between the two foot-bridge cables, for doing this work, and on trial they proved well adapted for it.

The difficult and dangerous problem, how to get the wire ropes across the river, and over the streets and buildings from one Anchorage to the other, was safely and expeditiously solved, in the following manner:

The two travelers were the first to be taken over. The reel containing the first rope was placed on a wooden axle, in a frame on one of our stone scows, at the foot of Brooklyn Tower. The end of the rope was then hoisted over the tower, and drawn down into the yard, where a Manila rope leading to a steam engine at the Anchorage was attached to it, and it was carefully hauled to the Anchorage and made temporarily fast there. Fenders and trestles were erected, and men were stationed on the roofs of the intervening buildings, to protect them. The operation was entirely successful.

The scow containing the reel with the remainder of the rope, was then towed over the river to the dock at the foot of New York Tower, and the bight of the rope as it unreeled, was allowed to sink to the bottom. The scow was made fast to the dock, and all the rope on the reel was coiled at the foot of the tower, after which the end was hoisted to the top of the tower, and drawn down and fastened to one of the grooved drums of the stone hoisting engine.

It was at first supposed that the ropes would have to be hoisted out of the water on a Sunday morning, when there were few vessels in the way; but by frequent observations I learned that we could get from 4 to 8 minutes clear water, on any day of the week, and it was resolved to make the attempt as soon as we were ready.

Engineers Martin and McNulty took position in the roadway of the tower, to watch for an opening. Foreman Dempsey, with some workmen was left on the top of the tower; while I clambered up on the hoisting frame to note the deflection, with William Brown, carpenter, to pass signals to the engineer of the hoisting engine, when to start and when to stop.

A tedious wait of more than half an hour followed. At last I heard from Mr. Martin the welcome words, "Go a-head!" and passed them to Brown, who signalled the engineer. In a few seconds the rope began to move; there was a ripple around it in the water; it began to draw away from the dock toward Brooklyn, and soon we could see the other part coming from Brooklyn towards us. Faster and faster the space of clear water between the two parts narrowed, and in four minutes from the time of starting, it swung clear of the surface of the water, with a sparkling *swish*, amid the cheers of spectators, on the wharves and ferry boats, and the shouts of our own workmen.

Up went the rope, and when it reached the level of the roadway, the engineer was signalled to go slow, and the speed lessened. When it was within a few feet of its proper deflection, 80 feet, I passed the word to slow the engine, which was done, but not until the rope had reached a point somewhat above the intended deflection, though in time, however, to prevent any damage to the rope. This occurred August 14th. The second rope was taken over in the same manner, on the same day.

These ropes were securely fastened on the top of the tower, and the two ends were then hauled over the streets and roofs, to New York Anchorage, much in the same manner as in Brooklyn. The ends were next spliced together, around the driving and guiding wheels, thus forming one endless rope, capable of being worked to and fro, to draw loads and to carry burdens. It is arranged to run in wood-lined wheels on the towers, and although it has seen much hard service, it bears no perceptible marks of wear.

The two parts of the other traveler were taken over by being lashed to the first one, and then carried over by steam. After being taken over, the ends were secured on the two anchorages, and the lashings were cut loose by men seated in "boatswain's chairs"—rude contrivances much used by riggers—which were arranged to slide on the first traveler. This somewhat novel feat was skillfully accomplished by Timbs, Supple, Cohne and Carroll, on the first rope. The second was cut by Miller, Arnold, O'Neil and myself.

The carrier was got over in the same manner as the first travelers—through the water. The tug, in towing the scow across, made a detour down stream, so that when an attempt was made to draw the rope out of the water, the side strain was so great as to pull it out of the 3-feet wooden wheel, in which it was running on the tower.

James O'Neil was injured at that time, by being struck by a piece of plank, which was thrown against him by the falling rope. This accident, I am happy to state, is the only one which has happened on this part of the work. The rope was replaced in the wheel, and a guiding sheave was put on it outside of the tower, and it was then hauled up without further difficulty.

After being hauled out of the water, the end was taken from the grooved drum, and hoisted to the tower again, on the land side, and fastened to a snatch block which ran on the traveler. A Manila rope, some 300 feet long, was made fast to the end of the carrier, and the block was allowed to slide down on the traveler, toward the anchorage, carrying the end of the wire rope with it. It ran down 350 feet by its own gravity the bight remaining coiled on the dock. When it would go no farther in this way, men pulled it along to the Anchorage by the Manila rope. There a tackle was attached, and it was strained up to its correct deflection, by steam, and fastened by a socket and stirrup. I found it lessened the danger and the labor, to hang the end of the rope to the traveler, as above described.

To get over the five other large ropes, I adopted the plan which I used so successfully at Niagara Falls, namely: by suspending the weight of the rope to be hauled on the carrier, and hauling by the traveler, or a Manila rope, worked by a steam engine. The first cradle cable was hauled by the traveler; but this plan did not work well, owing to the frequent slipping and breaking of the belt, which transmitted power to the machinery. This rope was landed in New York, and it cost much labor to get it into position for running over, besides our trouble with the traveler.

It was therefore determined to land the remaining ropes at the foot of Brooklyn Tower, which would bring them at once into position; and to do the hauling by a Manila rope, worked on the grooved drum before mentioned. The operation was conducted as follows:

The Manila rope was first drawn over the river by the traveler, and made fast temporarily on Brooklyn Tower. It was suspended from the carrier by small clevises, which prevented the bight from dropping in the way of passing vessels, and at the same time allowed it to move freely. These clevises were put on 80 feet apart. Another rope was drawn up from Brooklyn Anchorage in the same manner, and one from New York Anchorage.

A stick of oak timber, 6 x 10 inches and 10 feet long, was fastened by stirrups on the top of the carrier just outside of Brooklyn Tower, on the water side. To this a large grooved cast-iron pulley was hung. A 14-inch leading block was also made fast to this stick, near the iron sheave, and through it a $4\frac{1}{2}$-inch Manila rope led to an engine on the dock. By this rope the end of the wire rope was hoisted from the reel on the dock below, and run over the iron pulley. The hauling rope from New York was then made fast to the end of the wire rope, and the New York engine was started, and with the aid of the dock engine in Brooklyn, the wire rope was hauled 10 feet toward New York, and then the first hanger was put on.

These hangers were grooved iron sheaves, 8 inches in diameter, to which a pair of "sister hooks" were attached, in such a way as to allow of their being opened and slipped over the carrier, in the most expeditious manner. The cables were lashed below the hooks by $\frac{1}{2}$-inch hemp ropes. Thus the hauling line pulled the cable along, while the hanger ran easily on the carrier, and held the weight of the cable lashed below. The hangers were put on about 60 feet apart. The oak stick was used to prevent the carrier from being strained, at too sharp an angle, by the weight of the cable and hoisting line. A buggy hanging on the traveler was used for two men to stand in to put on the hangers.

In this way a cable was drawn to the New York Anchorage; a line from that anchorage being attached as soon as the end of the cable reached the tower. It was necessary to use the line at Brooklyn Tower to assist in lifting the weight of the cable, until 350 feet had been run out, after which the New York line did all the work. I also had to "fleet" the New York line 400 feet, on the main span, to help the line from New York Anchorage.

When the end of a cable reached New York Anchorage, a wrought iron socket was put on, and it was attached to an anchor iron in the masonry by a stirrup. Meanwhile the end remaining on the reel was taken off and coiled on the dock, and then hoisted to the top of Brooklyn Tower, and hauled to the anchorage by the line before mentioned, the weight being held by hangers on the carrier.

The cable was next strained up until the hangers were relieved from its weight, when they were taken off by men who went down in buggies for that purpose. The buggies ran on the carrier, and were hauled back by the traveler. The cable was strained up still further, to the required point of deflection in the centre of the main span; then it was cut off, and an attachment was made by a socket and stirrup, as in New York. On the towers the cables ran on two grooved oak wheels, 3 feet in diameter, and 6 inches thick. When a cable had been taken over and fastened, it was lifted out of these wheels by powerful screws, set in a strong frame, and lowered on to permanent oak blocking. This plan was pursued with two foot-bridge cables, and two cradle cables.

Nearly four days were consumed in getting over the first, by the traveler, and fastening it; while the last one was drawn over in less than nine hours, and fastened in less than five hours more; thus showing the superiority of the last plan over the first, and the increased efficiency of the workmen through practice.

The cradles, ten in number, are nearly finished. Those in the main span are nearly 48 feet long, and so arranged that the strands of the main cables will be within easy reach of the men who are to regulate the wires The four cradles in the land spans are about 7 feet shorter than the others, owing to the fact that each pair of cables will be 14 feet closer together on the anchorages than they are on the towers. The cradles are made of oak, in the most substantial manner, combining lightness and great strength. They are 4 feet in width. The centre of the floor is made in part of iron rods, so as to admit of the free passage of the wind, and thus reduce oscillation.

The foot-bridge, which is to extend from one anchorage to the other, over the tops of the towers, will be made of oak slats 3 x 1½ inches, laid directly on the cables, with 2-inch spaces between the slats, for the free passage of the wind. The slats are held in place by longitudinal strips 3 x 1½ inches, to which they are fastened by round clinch nails. When the floor is laid these strips will lie directly over the cables, to which they will be secured by U shaped stirrups, plate washers and nuts. This floor is all put together in sections of 12 to 16 feet, and as soon as the storm cables are attached, it will be laid.

When all the cradles are in position, each half of a traveler will have 7 supports between the anchorages, namely: one on each of 5 cradles, and one on each tower. Those on the towers will be made of 3 wood lined sheaves, placed a short distance apart; those on the cradles will be single sheaves. Numerous wooden rollers will be required for the guidance of the wire when running out; but the position of many of these can be determined only by actual trial, when running the wire.

The carpenter work, blacksmithing and machinery (of which I have the general supervision), are of such a varied miscellaneous character, that the work is tedious to itemize and difficult to describe. It may suffice to say that a great part of the work in these departments, during the past year, has been directly or indirectly connected with the preparations for cable-making; and that it has been well and faithfully done, and probably as cheaply as was compatible, with a due regard to strength and safety. (Mr. A. H. Smith has had immediate charge of the machine shop and steam engines, while Mr. Downey has turned out excellent work from the blacksmith shop.)

I have anticipated much trouble in instructing inexperienced men in the details of cable-making, as we have only one man who has ever seen anything of the kind; but the intelligence and skill displayed by the workmen in these preliminary operations, lead me to think that I may have overestimated the difficulties to be overcome.

It is a matter of history that the river was first crossed on one of the travelers, August 25, and I wish to state here, that the transient notoriety attending the affair somewhat annoyed me. I had a natural desire to cross first, but my principal object was to show my workmen, who were to follow under more dangerous conditions, my own entire confidence in the strength and security of the work.

Foremen Smallfield, Dempsey, Young and Cohne have rendered efficient service.

I have carried out your instructions to the letter, unless in cases where you have given me discretionary power; and, from my perfect familiarity with your plans, and my own experience, I shall expect the cables of this bridge to equal, if they do not excel, the best that ever were made.

All of which is respectfully submitted,

E. F. FARRINGTON,

Master Mechanic New York and Brooklyn Bridge

Brooklyn, December 30, 1876.